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Topics of the Month

In defence of technology

ONE of the most distinguished men to receive the Messel Medal of the Society of Chemical Industry, Lord Cherwell, F.R.S., had some very strong criticisms of the neglect of technological education in this country when he delivered the customary Medallist's Address at the S.C.I.'s annual meeting at Liverpool recently. Lord Cherwell has been Professor of Experimental Philosophy at Oxford since 1918, but he became a public figure through his close association with the Prime Minister, Sir Winston Churchill. It is only recently that he gave up his Cabinet post as Paymaster-General. He is still the P.M.'s personal advisor on atomic energy and other scientific matters and a few weeks ago he was appointed to the Board of the new U.K. Atomic Energy Authority.

Lord Cherwell began by criticising the small number of university chemical engineering departments in Great Britain, pointing out that the subject was an exceptionally difficult branch of technology lying at the root of many forms of industry, not the least of these being nuclear energy production. He compared educational facilities here unfavourably with those in countries possessing technological universities. It was quite wrong, in his view, to confine teaching in the higher branches of technology to the ordinary universities. To offer a general education in technology, dozens of different departments were required and scores of professorships. To pay for these, at least a million pounds a year would be needed and such an expenditure could only be justified if something like 3,000 or more students were being trained. No university in this country, save London, would welcome an influx of 3,000 technological students and 50 or so technological professors. It would throw the whole place out of balance. This was why we ought to have proper technological universities in order to get the best technological experts in sufficient numbers. One of the obstacles which stood in the way of this objective was the 'ridiculous intellectual snobbery' concerning technology which unhappily pervaded this country. For some obscure reason it was considered in many influential circles that technological competence was not on par socially or intellectually with knowledge of the older subjects. Lord Cherwell thought that it was impudent of arts men to look down upon people who frequently knew far more about the arts subjects than the arts men did of technology. 'Quite frankly,' he continued, 'I resent this attitude very much. I think it more important to know about the properties of chlorine than about the improprieties of Claudius. The people who are keeping this country alive are the people who are producing saleable products whether it be in the chemical, the engineering or the textile fields. I consider

it scandalous that this country does not recognise that it takes just as much brains to become a first-class technologist as to become a first-class lawyer—probably more.'

Lord Cherwell admitted that he had fought this battle for the last 20 years but without any great success. Unfortunately the men who ran our administrations were very seldom technologically minded and, despite what was said, somehow or other nothing very much was ever done.

The £ s. d. of synthetic rubber in South Africa

SOUTH AFRICAN consumption of rubber has increased by 75% over the past five years and annual imports are about 30,000 long tons. Although the quantity concerned is not large, the rapid upward trend in consumption is significant, and increasing consideration is being given to the possibility of establishing a synthetic rubber industry in the Union. The prospects are enhanced by the starting up of the large Sasol oil-from-coal plant, which could be a source of raw materials.

If there should be general agreement on the desirability of establishing such an industry, considerable thought would still have to be given to the question of the optimum size of a synthetic rubber factory in the Union. The production target can be put at anything from 10,000 to 20,000 long tons of Buna S rubber p.a. without any danger of this figure being regarded as unrealistic under the present circumstances. It stands to reason, however, that a factory with a capacity of 20,000 long tons of synthetic rubber p.a. should be the most economic production unit, although this may not necessarily be a unit of the optimum size that can be erected in the Union.

At the prevailing prices, the cost of the essential chemicals, some of which are not manufactured in the Union, will amount to some £90,000 for the production of 20,000 long tons of rubber. It should be possible to produce the 650 tons of hydrogen needed in the Union at a cost of about £30,000. More indirect process materials such as coal (required for the generation of steam), water, etc., and electric power will probably require another £50,000 annually. Expenditure in connection with catalysts should be more than offset by earnings from the sale of by-products which are left out of consideration in the calculation of production costs. If the possible local prices of 2s. per gal. for alcohol, 2s. 6d. per gal. for benzene and £10 10s. per long ton of carbide are applied to the two combinations of the required quantities of raw materials, it is estimated that the total costs of raw materials, including the cost of additional chemicals such as hydrogen, as well as indirect process materials and electric power, but excluding smaller items which may be involved, will be roughly as follows: (*a*) alcohol-benzene process, £1,698,750 for materials and services; (*b*) acetylene (*via* carbide) benzene process, £1,065,250.

Salaries and wages of employees should, according to normal South African rates, amount to not more than £500,000 a year. If considerable use can be made of non-European labour this figure would be very much lower.

It is conservatively estimated that depreciation will load the production costs of a synthetic rubber undertaking in the Union with a capacity of 20,000 long tons by some £500,000 a year. Miscellaneous costs not included in the foregoing estimate would mean an additional £160,000. Thus total costs for the first process would be some £2,858,750 and for the second £2,225,250. On these figures it should be possible to sell rubber made by either process profitably in the Union.

British newsprint mills in America

ERECTED at a cost of 60 million dollars (about £20 million), the Bowater newsprint and pulp mills which have come into operation at Calhoun, Tennessee, represent the largest investment of British capital in the United States since the war. The mills, which are operated by Bowaters Southern Paper Corporation, a subsidiary of the Bowater Paper Corporation Ltd., have an initial productive capacity of 130,000 tons of newsprint and 55,000 tons of sulphate pulp per annum.

Announcing the starting up of the mills within two years of ground being first broken on the site, Sir Eric Vansittart Bowater, chairman of the parent company, pointed out one feature that is probably unique: the entire production of this plant has from the outset been sold under contracts for 15 years ahead. The coming into production of the Tennessee mills will help materially to relieve the great pressure on Bowater's Canadian mills which during recent times have been hard pressed to supply all the needs of its customers on the North American continent. The sulphate pulp produced at Calhoun is surplus to the mills' own requirements of this material and it is therefore available for shipment to other paper mills, including the Bowater mills in the U.K.

The site for the mills covers a little more than 1,800 acres. A large afforestation programme has been started, as a result of which some ten million pine seedlings will have been planted by the end of this year. Apart from that programme, there is a large quantity of Southern pine, which matures in 25 to 30 years, and to conserve this for purposes of pulping a pond has been constructed which is large enough to take 10,000 tons of timber. About 700 people will be employed in the mills, with about 3,000 in the woods.

The use of hardwood, as an alternative to softwood, for making pulp is being considered in the Calhoun area. There is an ample supply of both.

Fuel research and chemicals

WHEN pyrites is roasted for the manufacture of sulphuric acid the residues of iron oxide are ordinarily mixed with iron ore and smelted in blast furnaces. It has now been found advantageous to use a type of burner at sulphuric acid works which requires finely divided pyrites and produces a residue unsuitable for smelting. At the suggestion of the National Sulphuric Acid Association Ltd., samples of these residues have been mixed with coking coal and carbonised in the intermittent vertical chambers at the Fuel Research Station to see whether a coke with a high iron content could be produced that would still be strong enough for use in blast furnaces. The results so far obtained are distinctly promising.

This is announced in the latest report of the Fuel Research Board (for 1953: H.M.S.O., 2s. 6d.), in which further information is given of the Fuel Research Station's work on the Fischer-Tropsch process, for which they are the centre of information in this country. Recent investigations of the synthesis of oils and chemicals have covered such widely different fields as, on the one hand, the purely chemical problems concerned with the development of suitable catalysts and the discovery of the best conditions to give the desired products, and, on the other, the chemical engineering problems that have to be solved before the process can be satisfactorily operated on a large scale. These include the

Comical Engineering Terms

"FLASH DISTILLATION"

design of reaction vessels for the different methods of working—with a fixed bed of catalyst, a fluidised bed of powdered catalyst, and a suspension of powdered catalyst in a liquid medium—taking into account the large amount of heat evolved by the reaction. In experiments with the large pilot plant using a water-cooled bed of fluidised iron catalyst, smooth operation has been achieved with a conversion of 92% of the synthesis gas and a daily production of about 60 gal. of products, including condensable gas, liquid hydrocarbons, wax, alcohols and other compounds containing oxygen. Fuller details of this work appear in this issue.

Work is in hand on the utilisation of fine low-grade coal and coke both as boiler fuel and for gas production. Observations have been made on the burning of such fuels in boiler furnaces of different types that may enable a grate to be designed without the use of very small openings, which tend to become choked with fine ash and fuel. On the gasification side, attention has been devoted mainly to the production of water-gas and producer gas from weakly-caking coal using the fluidised-solids technique. Originally much of the fuel was lost as dust and, although alterations to the pilot plant have now reduced this loss considerably, further reduction is necessary. A comparison has been made between rates of gasification in this continuously-operated plant and in a small intermittent laboratory-scale reactor; considerable progress has been made toward correlating the results obtained in the two ways. A slagging cyclone generator has been used with some success to gasify crushed coal using a blast enriched with oxygen.

The report also gives details of progress during the year towards perfecting the Fulham-Simon-Carves method of washing flue gas with ammonia to remove sulphur compounds and recover ammonium sulphate and sulphur. It is shown how basic investigations of the vapour pressures of the ammonia-water-sulphur dioxide system have helped this work.

Murdoch's new industry

THE BICENTENARY of William Murdoch's birth, which falls on September 21, should be an occasion for re-assessment rather than repetition of the usual biographical material. Coal-gas brought coal-tar with the consequent chemical industries producing dyes and intermediates, a result which came after Murdoch's time. Yet on looking back we see how this versatile Scot was someone far more important than a miller's son who was so mechanically minded as to anticipate Trevithick with his high-pressure engine. Murdoch did no more than others had done before him when he distilled or carbonised coal in a kettle by the fireside at Redruth. But after Boulton and Watt had been at last persuaded that there was something in this craze of Murdoch's for converting coal to a gas for illumination purposes, and after Murdoch had called their bluff by resigning his job since they refused him a salary increase to two guineas a week, then things began to move. Boulton and Watt recalled Murdoch to be manager of the Soho foundry at Birmingham at a thousand pounds a year—a remarkable change of face! But far more than this, there was the creation of a new industry which was one of the first in chemical engineering, the coal carbonisation industry which brought considerable business to Boulton and Watt. In 1806-7 the Soho firm were called upon to furnish thousands of feet of gas-piping, thousands of burners, retorts, gearing for fitting retorts and much other plant for an industry born literally at the fireside. A pioneer or pilot plant was available in the gas-lighting installation sent by Boulton & Watt to the cotton mills of Philip & Lee in Manchester. 'We are now preparing our gazometer pits and have determined to appropriate six instead of four gazometers,' wrote the Manchester firm to the Soho partners, following this with orders for 'best fire-bricks for seating the centre bottom of the retorts.' In addition to carbonising plant there was purification plant to be installed, especially after Dr. William Henry of Manchester had studied this problem at the Philip & Lee pilot plant. Murdoch devised various washing and purifying methods to avoid the 'Soho stink,' as it was called, and designed horizontal retorts of elliptical cross-section after the circular-section type had proved less efficient. 'Let William be sent for,' was the call whenever the Soho partners came across a problem or actual breakdown, and this brings the inevitable conclusion that Boulton & Watt would have achieved far less without Murdoch's genius.

A final point to be emphasised on this bicentenary is that neither the Moravian business man Winsor, who lighted the Lyceum Theatre by gas, nor Samuel Clegg, who was a one-time employee of Boulton & Watt and thus adapted ideas of others, can be regarded as any rival or co-discoverer of the new industry. Only one other shares the honour, and that was the French engineer Philippe Lebon. After his training at the Ecole de Ponts et Chaussées this young but unfortunate French pioneer illuminated his house in Paris by gas—but it was inferior wood-gas from wood distillation that he used. Before this same Lebon was mysteriously assassinated in the Champs Elysées he became a father of the wood distillation industry, producing wood

creosote for timber-preserving as well as the low-quality gas which was ousted by coal-gas almost at once. Gregory Watt was in Paris at the time when Lebon was lighting his house and attracting the crowds; hence he wrote to Boulton & Watt to urge them to make haste if they intended to take up the illuminating-gas craze of Murdoch. Murdoch and Lebon thus go down in history as fathers of our carbonisation industries, the one industry known in every town and city, the other now almost defunct except where wood waste is plentiful.

Beryllium refining by a new process

A HIGH intensity arc, similar to that used in large military searchlights but not usually found in industrial processes, is used in a new American process for refining beryllium which is expected to bring down the cost of producing the metal and to open up new fields of use for it. The process has been developed by Light Metals Refining Corporation of New York, and they are planning to build a control-type plant in the New York area for the production of 10,000 lb. p.a. of beryllium.

In the first step of the process, the raw ore is crushed and made into rod-shaped electrodes containing about 30% of low-grade soft coal. In the next step the rods are baked to make them electrically conducting and then are consumed continuously in an arc furnace by means of a high intensity arc, struck between the opposing ends of two such rods, which causes the material of the rods to vaporise rapidly from the ends. The temperature achieved is estimated to be in the range of 15,000 to 20,000°F.

Thus, the ore material is completely broken down to its elements and ejected from the arc into the atmosphere of the furnace as a high speed jet. Chlorine gas is simultaneously fed into the furnace and mingles with the vapour jet as it cools, and the metallic constituents of the ore are converted quantitatively to their chlorides. The chloride vapours are then piped to a series of condensing chambers in which each of the different chlorides is successfully condensed out in pure form. As a result, not only is pure beryllium chloride obtained but also, in the case of beryl ore, sizable quantities of pure aluminium, iron, and silicon chlorides. These constitute valuable by-products at no extra cost.

The final step in the production of the metal is the electrolysis of beryllium chloride directly to the beryllium metal and to chlorine gas, the latter being then returned to the process.

The use of beryllium in industry has up to now been limited because of the high cost of production by present methods and because the metal produced is so brittle that it cannot be machined readily by conventional means, and, generally, fabricated forms must be made by powder metallurgy techniques. This increases the cost of finished parts to two or three times the cost of the metal. It is believed that the cost of beryllium metal can be cut by as much as 75% by the new process, which is said to yield a nearly pure, non-brittle and readily machinable metal.

The plant to be set up by Light Metals Refining Corporation will enable production to be combined with research, so that the company will receive some income while at the same time perfecting the new process under actual production conditions. Apart from its use for beryllium production, it is stated that aluminium, magnesium, lithium, titanium and tungsten could also be refined by high intensity arc smelting.

Combustion gases and corrosion

FOR the past ten years the British Coal Utilisation Research Association has been studying the corrosive nature of combustion gases. Although the main emphasis of the study has been directed towards the solution of the problem of corrosion of air heaters and other heat exchange surfaces in water-tube boilers in the electricity generating industry, much information has been obtained which is applicable to the domestic and industrial fields of coal utilisation.

The results of the B.C.U.R.A. research are described in an exclusive article in the August issue of our associate journal, CORROSION TECHNOLOGY, by Dr. G. Whittingham, superintendent of B.C.U.R.A.'s combustion department. The six-page article with its eleven illustrations gives full details of findings. Two main conclusions are:

(*a*) With low-sulphur fuels chemical attack by sulphur trioxide (either in the gaseous form or as a condensed film of sulphuric acid) is not likely to be a problem. Corrosion is most likely to occur during banking or idling periods when excess moisture may be present and the flue gas and flue surface temperatures are comparatively low.

(*b*) With high-sulphur fuels the corrosive nature of the gases, particularly from closed stoves or boilers, can be quite high; trends in the increasing use of smokeless fuels would tend to increase the proportion of sulphuric acid in the gases.

This important article is typical of the high editorial standard already achieved by CORROSION TECHNOLOGY. Among the leading corrosion scientists whose contributions have been published is Dr. U. R. Evans, F.R.S., Reader in the Science of Metallic Corrosion at Cambridge University, and one of the world's foremost authorities.

Subjects already dealt with in the new journal include Cathodic Protection, Corrosion Inhibitors, Fretting Corrosion, Corrosion in the Motor-Car, Testing of Rust Preventives, Aluminium Cable Sheath Corrosion, Paint versus Corrosion, Electrochemical Derusting, Hot Dip Galvanising, Cutting Fluids and Corrosion, and Corrosion in Relation to Welding. Full and up-to-date reports of conferences dealing with corrosion and its control regularly appear. In the short period of its existence CORROSION TECHNOLOGY has undoubtedly established itself as the leading European journal in its field, publishing regularly some 50% more editorial than comparable journals. Subscription orders may be placed at the rate of 40s. for one year (12 issues) or 100s. for three years. They should be sent to the publishers at Stratford House, 9 Eden Street, London, N.W.1.

South African food machinery market

SOME useful pointers for British makers of food processing machinery who wish to export to South Africa are contained in a market digest which has been compiled by the Export Services Branch of the Board of Trade. It is thought that the total value of this particular market might be in the region of £1½ million annually, and Britain's share of this business in post-war years has been substantial, perhaps 60 to 65%. Competition from the Continent, however, shows signs of increasing and Germany must be looked on as a dangerous potential rival. The position of the United States may well be greatly strengthened as a result of the relaxation of restrictions on dollar expenditure at the end of 1953.

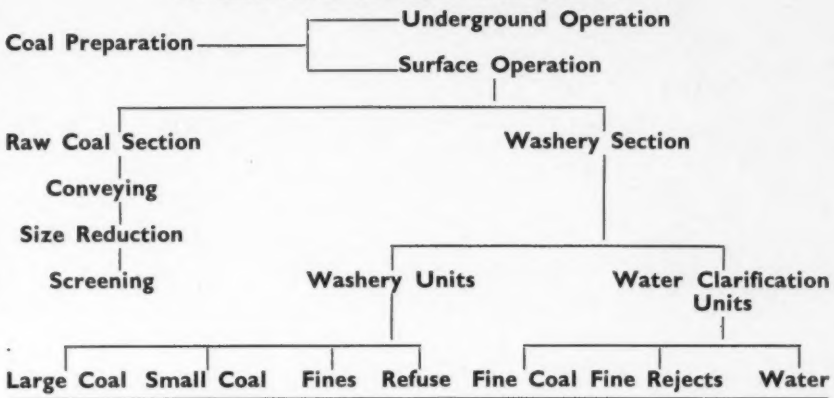
Chemical Engineering and Coal Preparation

By A. T. Steadman, M.Inst.F., A.I.Min.E., G.I.Chem.E.

The chemical engineer has made great contributions to the better utilisation of coal for gas making and for the manufacture of chemicals. Here the author seeks to show the opportunities for the chemical engineer in the preparation of coal for sale. Among the operations involved are materials handling, size reduction and screening. However, it is in the washing of coal that the most interesting chemical engineering problems arise and there is considerable scope for the engineer in designing better washing and separation plants.

EVERYTHING that happens to coal before its employment is preparation and almost all processes of coal preparation are fundamental chemical engineering processes. Coal preparation begins underground at the coal face, but for our purpose we can start at the pit top and study events from there. A typical scheme of operations is given in the accompanying chart.

OPERATIONS IN COAL PREPARATION



Raw coal section

In this section coal is being handled and dressed en route to the washery section of the plant. A rough sequence of operations is:

Mine car creeper
Mine car speed controllers
Mine car skotches
Tipplers
Screens
Pickling belt or sorting table
Pick breaker
Screens again
Roll crushers
Conveyors

Chemical engineers can interpret these operations in their own way, such as conveying, size reduction, size separation, etc. Briefly, then, this is a typical picture of a modern pit top.

Washery section

Here raw coal is cleaned and sized, the end products being coal, middlings and dirt. In a modern plant, these may take place as follows:

(*a*) Dense medium washer for coal, say 8 to $\frac{1}{2}$ in.; hydraulic-type washer for coal, say $\frac{1}{2}$ in. downwards; or

(*b*) Dense medium washer for, say, 8 to $\frac{1}{16}$ in.; froth flotation unit for, say, $\frac{1}{16}$ in. downwards.

Water clarification

As large quantities of water are involved in all of the above processes, its recovery for re-use is essential. In many cases, clean water recovery also involves the recovery of the suspended fine coal. Methods of water clarification are froth flotation and flocculation, or both.

At this stage coal flow sheets become more and more complex and units are carrying out operations as diverse as:

Flow of fluids
Transportation of fluids
Size separation
Crushing and grinding
Mixing
Filtration
Extraction
Distillation
Evaporation
Hydraulic classification
Specific gravity separation

Transport of materials

One of the most important operations in a coal preparation plant is, of course, conveying. Several factors enter into this operation. Take the angle of repose of the material, which varies according to the size and composition of the coal; if a conveyor was erected above a certain critical angle depending upon these factors, the coal would not stay on the belt. At this juncture the designer must experiment to arrive at a suitable position for the bunker, using an economic length of conveyor at the correct angle of repose. Having decided this, the weight of steel in the structure must be calculated, as must the quantities of the different parts of the frame, the type of drums and the number of idlers. From the tonnage per hour of the coal the width of the conveyor and the thickness of the belt are calculated. The size of individual pieces of coal have an influence here. If it is a long conveyor it might be cheaper to include a means of breaking the coal down to say, 8 in. and using a narrower conveyor at less cost.

It is then necessary to decide on the type of motor and specify suitable reduction gear. Tension gear and holdbacks will be needed. In fixing the motor size a proved empirical formula must be employed to enable the h.p. to be worked out from first principles; the length, width and weight of the belt and the lift and tonnage per hour must be known.

Design economy

It is always advisable to aim for symmetry in design and, if possible, to avoid the use of diagonals.

Other items of equipment are necessary to make up a unit, or to make a unit part of a much larger unit. Suppose we are delivering the feed of coal from the pit top to the primary screen of a coal cleaning unit. We may begin with tipplers discharging coal on to a suitable conveyor. At this point, then, we shall require a suitable chute to deliver the coal from the tippler discharge to the conveyor belt. This chute must be fitted at the correct angle; if it is too steep the larger pieces may crash down and damage the belt. To prevent the material falling off the belt, skirt plates of steel or rubber are necessary.

At the delivery end we may be feeding either a washer or a screen directly or indirectly through a surge bunker. To balance the feed to a coal preparation plant it is now usual to fit a surge bunker, the capacity of which may vary between 20 and 100 tons/hr., depending upon the size of the feed and the quantity and the type of washer. If the coal is large, say 8 to 12 in., it may in some cases be advisable to have a small surge bunker which will

allow a larger bunker to fill if required to do so, owing to a breakdown at some part of the receiving plant. Alternatively, with a large bunker which is serving as a storage and surge, a spiral chute which reaches down to the throat of the bunker can be fitted.

Sorting and screening

The +8-in. coal must be cleaned, usually by hand sorting. The coal is fed on to a belt of rubber, plastic or steel sections and from 4 to 7 ft. wide. The dirt is picked off the belt and thrown into hoppers; sometimes a middling product is also picked out. Good lighting is essential here.

A more modern method and one which lends itself to the hand sorting of the difference in rank of coal is the circular sorting table. Good lighting is provided and the men, using rakes instead of bare hands, can sort out dirt and middlings, bright coal and dull coal. Much labour is eliminated when using a table such as this. A disadvantage of hand picking and sorting is the human factor; sorters get less discriminating as the shift wears on and they become tired.

A method of mechanical sorting, now being tested at pilot-plant stage, is being developed by the N.C.B. This machine utilises the difference in reflectivity of the different kinds of coal and, with the use of photo-electric cells and sorting arms, is said to achieve an efficiency approaching that of good hand sorting; theoretically there seems no reason why 100% efficiency should not be achieved.

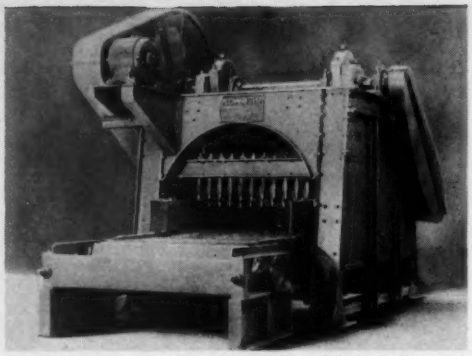
Controlled breaking

Probably the most useful type of machine for this purpose is the pick breaker, which employs 50 or 60 picks or spikes to break the coal to a predetermined size. The spikes or pickaxes split the coal at its weakest points on the lines of cleavage between the various banded constituents—shale, pyrites, bright and dull coal, etc. A plate belt is used with this type of breaker.

The Bradford breaker is another type; it can separate dirt from coal during the operation of breaking. The machine can be likened to a trommel from its circular shape, except that it has guides which convey the material to the discharge end as the machine revolves. If the machine is not overloaded all the falling pieces of coal are broken by the end of the travel, leaving only the hard material unbroken and resulting in the discharge of the rejects.

Having joined together the coal screened to −8 in. with the coal broken to 8 in., we have a feed of raw coal equal to that of the original run-of-mine feed less the amount of material removed by hand sorting or mechanical sorting.

Next to be used are the secondary raw coal screens, designed to deal with the maximum feed as cheaply and as efficiently as possible.



[Plowright Bros. Ltd.

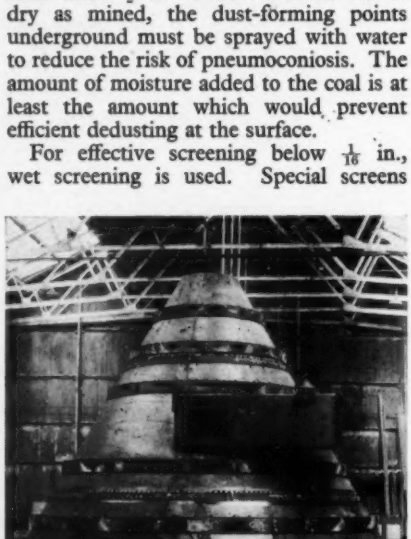
A pick breaker which incorporates 50 or 60 spikes or pickaxes for splitting the coal.

It may be necessary to make two products here, say plus and minus either 1, $\frac{1}{2}$, $\frac{1}{4}$ or even $\frac{1}{16}$ in. The design of the screen depends upon the load, the size analysis prior to screen, the size analysis desired in products and the moisture content.

It is always safest to design for a maximum final efficiency. In the design of this final raw-coal screen if the size analysis indicates a large amount of, say, 50% over 3 in. and we are screening at $\frac{1}{2}$ or $\frac{1}{16}$ in. for our final product, it is wise to fit a scalping screen to reduce the quantity of coal to be handled by the smaller meshes.

Moisture content has a great influence on efficient screening, especially in the sizes below $\frac{1}{2}$ in. Even when the coal is dry as mined, the dust-forming points underground must be sprayed with water to reduce the risk of pneumoconiosis. The amount of moisture added to the coal is at least the amount which would prevent efficient dedusting at the surface.

For effective screening below $\frac{1}{16}$ in., wet screening is used. Special screens



[Plowright Bros. Ltd.

An 18-ft.-diam. Chance cone being fabricated, showing middlings column and coal outlets.

fitted with water sprays are used. Screening is influenced by the load on the screen, the speed of vibrations of the screen and the quantity and force of water on the mesh.

There is no limit to the amount of water that may be used to achieve efficiency except to note that the water will have to be recovered afterwards. The fines, too, will have to be recovered, and the more dilute the effluent the larger will have to be the settling tanks, etc., and the greater the initial capital cost.

At this stage the following has been produced:

(*a*) A relatively dry intermediate product between 8 to $\frac{1}{16}$ in. with the following characteristics:

In.	*Size* %	*Moisture* %
8—5	30	5
8—3	50	6
8—2	60	7
8—1	65	7·5
8—$\frac{1}{2}$	70	8
8—$\frac{1}{4}$	85	10
8—$\frac{1}{16}$	100	12

(*b*) A $-\frac{1}{16}$-in. product with a certain amount of free water sufficient to convey it hydraulically to the cleaning plant, in this case froth flotation cells.

True chemical engineering has only just begun. We have an 8 in. to $\frac{1}{16}$ in. coal, a mixture of pieces and particles of material of varying specific gravity and sizes. We have to separate this mixture into clean coal, middling and refuse of a certain ash content. The coal is then to be classified into sizes, the middlings have to be crushed and rescreened in order to liberate the maximum amount of coal possible and the refuse must be disposed of.

We have also to separate from the $-\frac{1}{16}$-in. material the clean coal and to dispose of the refuse (tailings).

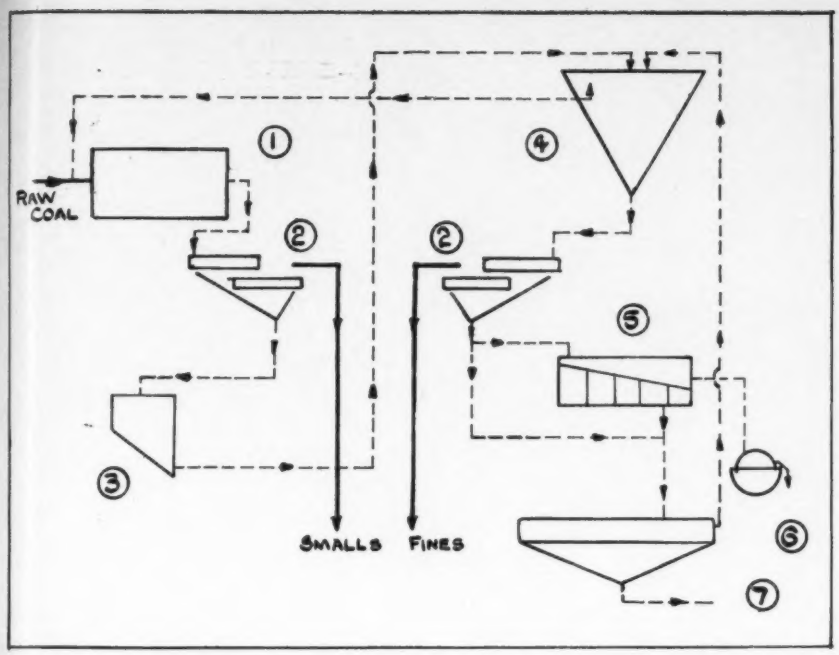
For cleaning the large coal (8 to $\frac{1}{16}$ in.) a variety of plant is used.

For large coal washing a hydraulic-type washer or a heavy medium type, or a true specific gravity washer can be used.

Classifier-type hydraulic washers

In the usual launder-type washer there are several variations of the same principle —stratification of a bed of coal, middlings and dirt of specific gravity increasing progressively from the top of the trough to the bottom, the bottom layer is being removed continuously as formed and without loss of coal.

The density in the bed of a stream of water in a launder increases from the top to the bottom of the stream depending upon the velocity of the stream; from our knowledge of the flow of fluids we can say that the mobility of the stream decreases with depth. Therefore, in an ideal launder there is a solid bed of material at the bottom and above this a layer of particles



FLOW DIAGRAM OF A TYPICAL FROTH FLOTATION UNIT

1 Washer unit
2 ¼-mm. and ¾-mm. screens
3 Fines sump
4 Settling cone
5 Froth flotation cells
6 Rotary vacuum filter
7 Thickener for tailings

travelling at a slow speed. As the surface of the stream is reached there are successive layers, although no definite line of demarcation, until the surface where the maximum velocity is reached.

The selective action lies in the fact that as the stream continues down the launder the hindered settling effect of the particles will control the fall of all particles to the bottom, the moving stream being the selective factor.

The sequence of effects of the combination of hindered settlement and stream selectivity is:

(*a*) Large heavy particles.
(*b*) Large light particles and small heavy ones.
(*c*) Small light particles.

If a launder is operated so that only (*a*) and (*b*) reach the bottom where stream selectivity is apparent, they will stratify and be removed in the following order:

Large light pieces.
Large heavy pieces.
Small heavy pieces.

The object is to control the process for removal of large light pieces. Then, by rewash of medium light particles, when the coal contains many middlings, an overall efficiency is obtained. The amount of rewash will depend upon the degree of selectivity desired, so that to wash a coal containing a large amount of particles of intermediate specific gravity would involve a large initial outlay in longer troughs and rewash troughs with subsequent additional maintenance and operating costs. It has not proved possible to achieve the ideal launder washer, owing to factors such as the turbulence of the flowing stream and the reduction in bed density owing to the withdrawal of heavy products and the entrainment of light particles.

Probably the best known type of launder is the *Rheolaveur*. It incorporates several refinements which tend to greater efficiency. Each trough has heavy material discharge boxes fitted at certain intervals along the bottom. The first few remove heavy dirt which has sunk first and has remained there, the boxes then remove lighter dirt. As we move progressively down the trough the operator, working with the chemist, decides at which point he can cut; the more middlings in the feed the more tedious is the operator's job, and the more desirable it is to have a constant feed.

Automatic shale extraction with an electro-mechanical device renders a modern *Rheolaveur* trough entirely automatic in action. Briefly, this control consists of the insertion of insulated electrodes in the sides of the washing troughs; any increase in the volume/depth of the bed of shale causes the water level to rise, submerging one or more of the electrodes and so closing a low-voltage circuit; a system of relays then operates the automatic discharge gear.

However, the greater proportion of coal washing plants used today employ some kind of jig, or Baum-type washer.

Jigging consists in the stratification of a mass of particles by means of up and down pulsations generated by a piston working in one side of a rectangular box, the other side of which contains a mass of particles. The oscillations may also be generated by compressed air.

In a common jig, stratification of what initially is a heterogeneous mass of particles takes place in a rectangular box, in the bottom of which there are perforations through which the pulsations pass. The strength of the pulsations determine the amount of and density of the particles falling through the perforations.

Specific gravity separation

There are certain processes used today for separating coal from heavier material which are true specific gravity separation methods. All are based on the same principle: if into a liquid of a certain specific gravity—*e.g.* carbon tetrachloride at 1.6 sp. gr. or a mixture of carbon tetrachloride and benzene at say 1.3—is placed a mixture of pieces of coal and dirt, the pieces lighter than the specific gravity of the liquid will float, the pieces heavier will sink and those of exactly the same density as the liquid will remain midway. We have here then a primary unit process.

Carbon tetrachloride and many other organic liquids are ideally suited for the separation of coal from dirt, the only drawback being the cost, both initially in the additional plant required for their recovery for re-use and the cost of the liquid itself. Although theoretically possible, it is not practicable to recover all the liquid used in the process.

Some years ago the Du Pont Co. of America developed such a process, involving the use of organic liquid medium, which was a striking example of a plant-scale laboratory process.

Floating on the surface of the liquid was a layer of water which wetted the coal on entry to the bath and helped to wash off the coal leaving the bath. The water also served to prevent the atmospheric evaporation of the liquid.

Final recovery of the medium was by spraying with water prior to the classifying screens. The spray water from products was filtered to remove any suspended solids, then the immiscible liquid was separated from the water, followed by distillation.

In a similar type of process where a solution of a salt is used as the heavy liquid, the whole of the recovered liquid must be purified by evaporation.

Heavy medium (Chance process)

The first specific gravity separation process for coal washing was the Chance sand flotation process, which is still being used.

The Chance plant consists of a cone with a chute for raw-coal feed, an overflow for clean coal out, and provision for extracting middlings and shale.

The suspension used in the Chance process is an artificial one of sand and water. The sand particles easily settle in water, so that some means of holding them in suspension in the water is required. This is done by means of the introduction

of rising currents of water, generally at the bottom side of the cone, and by means of bustle pipes spaced at intervals around the outside of the cone. Natural-wind-blown sand has the correct grading analysis.

To smooth out the variable currents created by the entry of the water a stirrer is provided rotating at 12 to 15 r.p.m. When a high-separating specific gravity is desired such as with anthracite coal, stirring only is usually all that is necessary. However, when cleaning bituminous coal and when the separating specific gravities are between 1.4 and 1.5 sp. gr., the vertical currents of water are necessary, being adjusted according to the analysis of the float and sink of the products leaving the process, the stirrer then only maintaining the sand/water mixture in an ' approaching stable ' condition.

The use of water currents and a stirrer is the reason why the Chance process is said to have an artificial medium.

The size of raw feed which may be dealt with in a Chance cone is usually 8 to $\frac{1}{16}$ in. Experiments have proved that a separation is possible when the diameter of the smallest piece of refuse is three times that of the coarsest piece of sand.

The reason why the apparatus used is a cone and not any other shape is because in a vessel with vertical sides there would be a varying density from the top to the bottom unless the sand used was of uniform particle size. To provide a sand like this would entail much additional expense and trouble.

By using a cone and sand of particle sizes ranging from 30 to 100 B.S.S. mesh, the upward velocity of the water entering at the bottom causes a progressive decrease in velocity up the cone due to the ever-widening diameter. Theoretically we require a coarse sand at the bottom of the cone where the velocity of the water is greatest and a finer sand at the top where velocity is approaching zero; therefore the the convenience of a conical vessel is made use of by employing a mixture of varying sizes of sand. A sand as mined can be used with little preparation beyond the removal of stones, etc.

The cone slopes at 60°, which is the most suitable angle to eliminate any possibility of silting up.

Middlings separation

Middlings separation is another special feature of the Chance process. Today it is nearly always necessary to separate out middlings, and to do this a close study of the washability characteristics of the coal is desirable.

Washability curves are important and, from the data obtained from certain seams, a final reconstituted run-of-mine feed is obtained on which the plant design is based.

The figures concerned are: a fixed percentage of middlings, plus and minus certain densities.

Ideally the middlings are floating midway or thereabouts in the cone. An outlet called a middlings tube is provided. This tube is arranged at the most suitable position down the cone for the middlings to float up; a current of sand/water near the base of the tube causes the middlings to float up and out the tube.

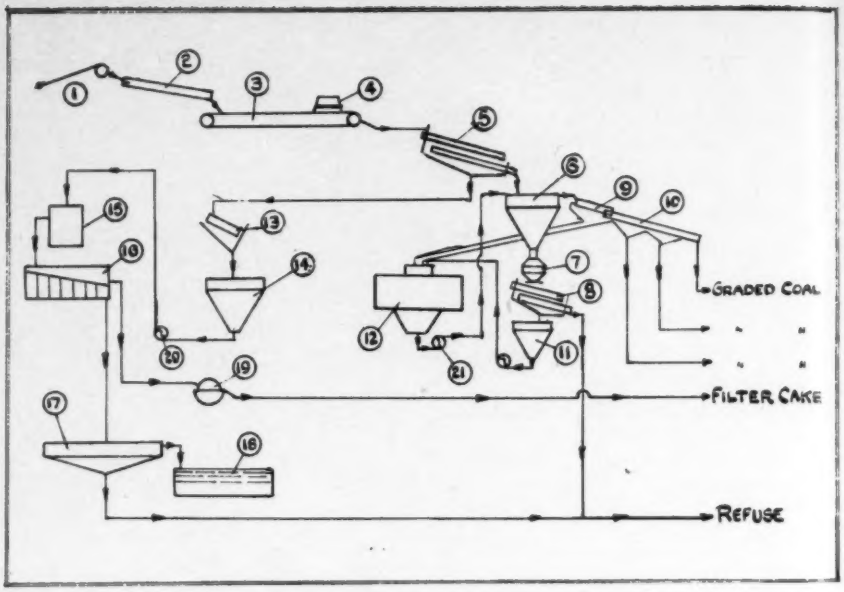
The quality of middlings can be fixed as desired; this is important because there are roughtly three kinds of middlings:

(*a*) Homogeneous.
(*b*) Heterogeneous.
(*c*) A mixture of (*a*) and (*b*).

It is common today to crush middlings and rewash, either in the Chance cone or mixed with a smaller-sized grade which is being treated in another washery. If the middlings are heterogeneous this crushing will release banded coal and dirt, but if the middlings are homogeneous nothing is gained by crushing and rewashing. If these homogeneous middlings are crushed and recycled back into the washing circuit they would only tend to cause a bottleneck in the middle of the cone because they have the same physical characteristics as the original middlings. If this happened, the only thing to do would be to lower the density of the suspension and let them go away with the dirt.

We can crush (*b*) and obtain a mixture of coal and dirt. To crush (*c*) would depend upon the amount of middling material in the piece.

Float and sink and ash analysis of the middlings is necessary before deciding on their fate.



TYPICAL FLOW DIAGRAM OF CHANCE SAND FLOTATION AND FROTH UNIT

1 Run-of-mine coal	8 Refuse screens	15 Flotation conditioner
2 Primary raw coal screen	9 Descending screen	16 Froth flotation cells
3 Plate picking belt	10 Classifying screens	17 Thickener for tailings
4 Pick breaker	11 Refuse sand sump	18 Clarified water tank
5 Secondary raw coal screens	12 Main sand and water sump	19 Rotary vacuum filter
6 Chance cone	13 Electromagnetic rapid screen	20 Slurry pump
7 Refuse chamber	14 Fine coal sump	21 Sand pump

The Chance cone is particularly suited to middlings separation.

Whilst it is obviously good practice to separate out in two containers, *i.e.* (*a*) coal and middlings/shale and (*b*) middlings and shale, we can make use of the coarse nature of the sand and the flexibility of the upward currents to arrange an extraction of middlings covering a range of densities rather than the single density. In most coals today the run-of-mine coal contains a wide range of middling between the coal and the dirt.

Heavy medium (Tromp)

Another type of heavy medium washer is the Tromp process. Here, instead of using a relatively coarse sand 30 to 100 B.S.S. mesh at 2.60 to 2.65 sp. gr., a heavy mineral or ore is used. The ideal medium is magnetite as mined, sp. gr. 5 to 5.2, and ground down, usually in a wet ball mill, to 150 B.S.S. or approximately 0.1 mm. This material grinds down without forming a large amount of powder below the desired size limit, so that it is ideal for producing a controlled size range. A suspension of ground magnetite can be made up with water to a specific gravity of over 1.9.

A feature of the Tromp process is the progressive increase in specific gravity obtainable at any instant from the top of the bath to the bottom. If all required conditions are under control, density control of the bath is uniform.

This progressive increase in density from the top to the bottom of the bath means that, if the specific gravity at the top had been regulated at 1.35, the particles of coal could at any given instant be suspended in the bath, each separate piece being at the position in the suspension of its own specific gravity. If we visualise a vertical column of particles of coal, with pure coal at the top and getting progressively dirtier (higher ash content) towards the bottom, we find that the surrounding medium at any instant in time has a progressively increasing density from the top to the bottom, due entirely to the settling rate of the particles of magnetite and maintained by the controlled introduction of fresh magnetite. Middlings may be removed at any position on this hypothetical column according to the requirements of the market.

A feature of the Tromp washer which has not been publicised to any extent yet may be mentioned.

On the early type of Tromp plant (1939), refuse and middlings were removed by the well-known pin-and-link type of elevator. This method caused a great deal of wear, necessitating very frequent replacement of parts and daily inspection to guard against breakdown.

In the latest types the wearing parts, *i.e.* the elevator chain and middlings chain which in the original bath were under the level of the suspension, have been completely redesigned. The bath now consists of a tank in which is suspended a circular drum. The raw coal is fed to one end of this bath and the heavy shale falls on to the inner surface of this drum which is made in the form of a paddle wheel. The rotation of this drum carries this shale upwards and deposits it on to a belt conveyor running well above the liquid level.

By means of horizontal currents the middlings are carried to the opposite end of the bath and are extracted with a moving blade operated by cams, the clean coal being carried over the end of the bath by the action of the liquid.

In the Tromp process it is not necessary to use magnetite which is costly (£12/ton). Spathic ore or mill-scale costing only about £4/ton may be used quite successfully.

Heavy medium (Barvoy's system)

This is a float and sink system employing a medium which is more stable, *i.e.* the particles are more finely ground. The system uses a suspension of finely ground barytes of approximately sp. gr. 4.2 ground to 200 to 300 B.S.S. and clay (sp. gr. 2.3), giving a separating gravity of up to about 1.8 sp. gr. In more recent installations the medium used is finely ground shale (*e.g.* tailings from a froth flotation plant).

The nearly stable condition of the Barvoy's suspension permits great accuracy in separation. Whereas the large majority of washers only separate coal and middlings from the dirt, with this suspension it is possible to obtain separations based upon the rank of the coal alone, *e.g.* coking coal from non-coking coal. This is an important advance in the technology of coal preparation.

Conclusions

There are other aspects of coal preparation which are of interest to the chemical engineer, but space considerations forbid a full description of them. However, mention should be made of the cyclone washer, a small piece of plant which does a big job of work, especially in the field of fines cleaning. Here use is made of centrifugal force to accelerate the settling rate and density classification of fines coal contained in slurries and the like.

Froth flotation and flocculation form another interesting field of chemical engineering study. Thickeners and filtering plant are used in flocculation when fines are recovered for re-use as a low-grade boiler fuel. Press filters are now being used to dry and manufacture slabs of recovered slimes and sludges which have been concentrated in the thickener by means of flocculating reagents.

In froth flotation, plant for the flotation of coal from dirt is being used and continuously developed, especially for coal dressing. Froth flotation, possibly more than other processes of coal preparation, is definitely within the province of the chemical engineer. The chemist also is very much involved because the bubble attachment necessary for lifting the coal particles to the surface of the liquid in flotation machines is dependent on surface chemistry.

* * *

To conclude, it is not out of place to question whether it is necessary to clean all coals. The writer's experience with varieties of coal on different kinds of furnaces has shown that clean coal is not always needed. A chain grate stoker, for example, does not require pure coal with ash content down to 2% or so. From a national point of view it might be cheaper to design a plant to burn coal with a relatively high ash content rather than to spend millions of pounds on more and more elaborate coal preparation plant.

However, looking ahead to the era of nuclear power for industry, one can discern a need for even better coal preparation plants than are available today. These plants would be required to prepare the coal in as pure a form as possible, not for burning but for chemical purposes.

Another field of chemical engineering in the coal industry is being opened up by the development of hydraulic means of transportation both underground and on the surface. The design of pumps and other apparatus for these systems opens up new fields of interest for chemical engineers.

This article is based on a lecture given by the author before the N.W. Graduates' and Students' Section of the Institution of Chemical Engineers on October 8, 1953.

Zone Melting makes Ultra-pure Metals

A NEW PROCESS called zone melting has been evolved by the Bell Telephone Laboratories of America for producing ultra-pure metals containing only 1 part impurity in 10 billion. It is already in use for the purification of germanium for transistors, whose operation depends on obtaining germanium in a highly pure form. Extremely pure tin and antimony have also been made and semi-conductors such as silicon and the compound indium-antimonide are refined by this process.

Technique

Zone melting makes use of the fact that impurities are not equally soluble in the solid and liquid states of a substance but are usually more soluble in the liquid state. A narrow molten zone, therefore, is moved along an ingot of relatively impure material and draws the impurities to one end. This is done by passing the ingot through a circular induction heater, which brings it to a molten state. The molten zone collects the impurities as the ingot passes through the heater, and the ingot solidifies into a purer state on the other side. A series of these circular heaters is used in practice and each molten zone extracts its share of impurities from that left by the preceding zone. By the end of the run, the impurities have been swept to one end of the ingot, where they are trapped. This section may then be cut off.

Purification achieved

The extent of purification that is attained depends on four things: the number of passes made; the initial impurity level; the difference in the solubility of impurities in the solid and liquid; and on how short the zone may be made. Impurities which raise the melting point may also be removed by zone melting, but the mechanism required is most complicated.

The sweeping action of the process, besides getting the utmost in purification, permits the identification of impurities which may be present in such small amounts that they do not permit positive detection by any of the available analytical devices. Because of this the process can be used as a research tool for laboratory investigations on the effects of impurity on various metals, as well as for manufacturing purposes. It is said to be applicable to any solute-solvent system in which there is an appreciable difference in the solubility of the impurity in the molten substances and in the solid freezing from it. The mathematical theory has been worked out, and the results to be expected for a given system can be accurately predicted if these solubilities are known.—*Product Engineering*, 1954, **25** (4), 189.

CATALYSIS

Metals as oxidation catalysts; ethylene oxidation; ammonia synthesis; reactions between carbon monoxide and hydrogen

By S. L. Martin, M.Sc., F.R.I.C.

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IN the previous review[1] metal systems as hydrogenation catalysts were discussed. Here, after a summary of some recent general literature and developments, recent work on the oxidation of ethylene over silver to produce ethylene oxide—of commercial importance in the manufacture of glycols—is reviewed by way of contrast to hydrogenation catalysis. There follows a digest of developments with catalysts for ammonia synthesis and for reactions between carbon monoxide and hydrogen to give various products; these in two respects have something in common—the use of iron catalysts and their interpretation as hydrogenation processes. The products from CO and H_2 depend not only on the nature of the catalyst but also on the operating conditions, and range from pure methane (with Ni) through fuel-rich or alcohol-rich products (Co, Fe) to high-melting paraffins (Ru) and aromatics (ThO_2). The term 'Fischer-Tropsch synthesis' is really applicable only to particular sets of conditions. Recent evidence implying that alcohols are the true primary products suggests that some form of description other than 'hydrogenation of CO' is needed to cover the general case.

Recent publications

The proceedings of a conference on cationic polymerisations and related complexes, held at the University College of North Staffordshire in March 1952, have now been published[2]; the contributed papers will also be of interest to those concerned with Friedel-Crafts catalysts. Neilson and Anders[3] have put out a monograph on promoted iron catalysts for ammonia synthesis; although this is now four years old, it contains useful material. In a somewhat similar category are the books by Kaines[4] and Storch *et al.*[5] on the Fischer-Tropsch synthesis, and by Kronig[6] who covers mainly developments at I. G. Farbendustrie on catalytic pressure-hydrogenation.

The papers[7] presented at a symposium on chemicals produced in the U.K. from petroleum raw materials, held in London in March 1953, contain useful production statistics which emphasise the rapid growth in the U.K. of catalytic processes for such purposes. There are at present five cracking plants with associated chemical processing units, and a number of smaller subsidiary processes. The estimated annual capacity is approximately 100,000 tons each of ethylene and propylene and 60,000 tons of C_4 hydrocarbons. These are used mainly for the production of ethyl alcohol; ethylene oxide (20,000 tons); plastics, and synthetic fibres based on styrene, butadiene, *iso*-butene and ethylene (360,000 tons). It is of interest to note a report[8] that a large plant for making catalysts for petroleum refineries is due to commence production in Britain in 1954.

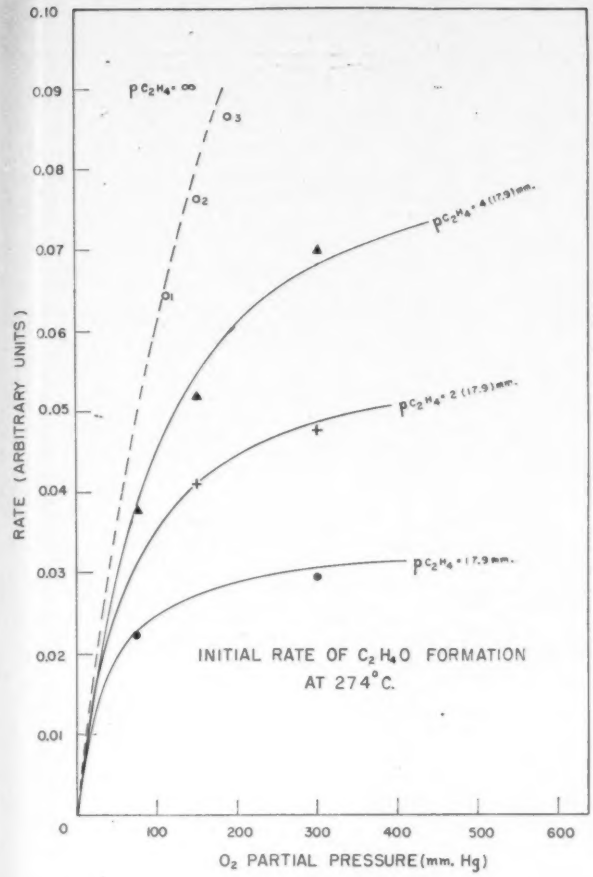
On the more fundamental side, a good review by Kemball on contact catalysis and surface chemistry has appeared.[9] A report on a discussion on the reactivity of free radicals[10] contains papers which will be of interest to those concerned with catalysis in solution. The last two issues of 'Advances in Catalysis'[11, 12] maintain the usual efficient and well-balanced reviews to which we are now accustomed, covering both fundamental and industrial aspects. Vol. IV contains two reviews on different aspects of hydrogen peroxide reactions, two on cracking processes and catalysts, two on fundamental aspects of adsorption, and others on acid-base catalysis, synthesis of gasoline from CO and H_2, and enzymic reactions of hemoproteins. In Vol. V there are articles on surface studies using vacuum micro-balance techniques (two); on the role of intermediates in reaction mechanisms (which emphasises that an intermediate formed from reactants may itself be the catalyst); on the general uses of Raney nickel, and on iron nitrides as Fischer-Tropsch catalysts; on the ammonia synthesis, the heterogeneous oxidation of CO by various oxides (in relation to effective materials for gas-masks), and on the 'oxo' process for hydrogenation of organic compounds with CO and H_2 synthesis gas over cobalt catalysts. Finally, in this volume there is a welcome review of contributions from Russian scientists to catalysis over the last few years. This is particularly useful, since Russian journals no longer carry summaries in other languages and their leading men contribute papers to journals in other countries less and less frequently.

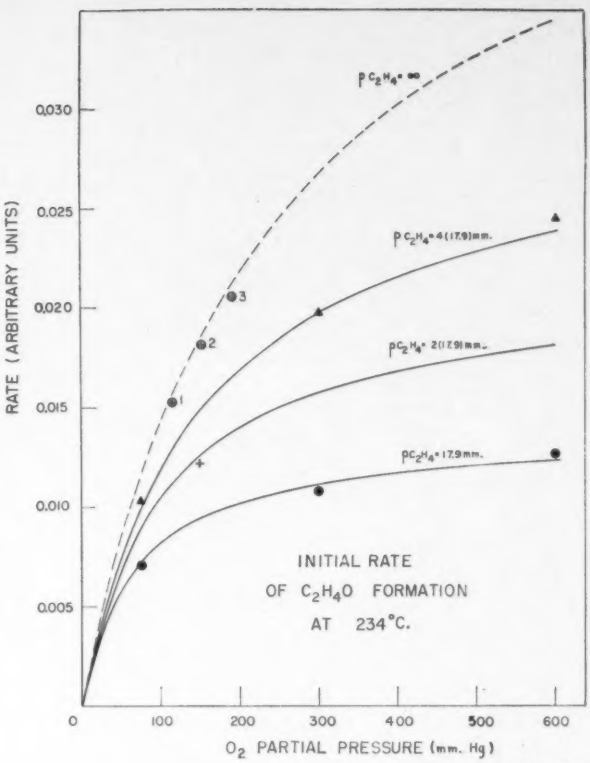
It is pointed out that production based on catalytic processes for synthetic fuels, rubber, plastics, sulphuric acid, fat and oil hydrogenation increased in Russia from 0, 85, 0, 1,600 and 118 respectively in 1938 to 900, 250, 30, 2,500 and 250 thousand tons respectively in 1950. The views of the three main schools of thought on the nature and role of catalysts are compared and contrasted, and the main criteria which are being used in attempts to modify catalysts are summarised. A list of 460 references is given.

Metals as oxidation catalysts

Typical of oxidation processes are CO to CO_2, hydrogen to water, ethylene to ethylene oxide, and hydrocarbons to 'intermediates' such as alcohols, aldehydes and ketones or completely to carbon dioxide and water. Of importance with hydrocarbons, therefore, is the selectivity of the catalyst. Many *oxide* systems are highly active catalysts. As emphasised by Garner (ref. [13], p. 211), these are nearly all of the semi-conducting type, possessing lattice defects to a more or less marked degree or capable of being easily reduced to the metal or to a lower valency state. The *metals* which themselves show any marked activity are those whose oxides fall into this last category—copper, silver, gold and the platinum and palladium groups. In common, they are all able to chemisorb oxygen—and in some cases carbon monoxide—fairly strongly, although they resist formation of stable oxide films, that is are not readily oxidised. The nobler the metal the higher the temperature usually required for catalysis by compact material or the greater is the state of sub-division necessary to permit use at lower temperature (*cf.* platinum black).

In his summary of work on oxide systems, Garner emphasises two points: the relative mobility of surface oxygen (as distinct from that within the crystallites) even on refractory materials such as aluminium oxide; and the formation of pure metallic nuclei with oxides such as cuprous oxide. In the latter case, a reactant (*e.g.* CO) 'picks up' an oxygen ion from a lattice point, releasing electrons which with the metallic ion gives a metal atom which can then diffuse through the surface layer of oxide to build up surface





[*Courtesy: Canad. J. Chem.*

Fig. 1 (*left*) **and Fig. 2** (*above*). **Rates of formation of ethylene oxide as a function of reactant partial pressures at 274 and 234°C. respectively.**

nuclei of metal. It appears to be implied that these nuclei may then take up gaseous oxygen-reforming oxide which contributes to a repetition of the cycle. On the other hand, for silver catalysing ethylene oxidation, the data of Orzechowski and MacCormack[14] indicate strongly that the true catalyst combination may be surface silver oxide-free silver. It is well known that with highly dispersed metals with large accessible surfaces a fair proportion of the metal in the presence of oxygen must exist as a surface complex with oxygen. Therefore, in the opinion of the reviewer, differences in the results obtained with oxide and equivalent metal catalysts may well be ones of degree rather than of basic mechanism—the common metal-oxide heterogeneous surface ultimately formed after an initial period of use may provide a base for the necessary electronic transitions between chemisorbed and gaseous reactants.

Oxidation of ethylene over silver catalysts

Borrows and Caplin,[7] comparing the economic aspects of silver-catalysed direct oxidation and the chlorohydrin indirect processes for making ethylene oxide, conclude that in Britain the latter will give the greater annual profit, providing the full oxidation reaction to CO_2 and water can be kept below stated maxima. Opinion appears to favour silver suitably dispersed on refractory oxides and promoted with alkaline earth metals. There are certain claims that substances such as ethylene dihalides and amines act as anti-catalysts for the CO_2 reaction.

In their four papers presenting the results of work started several years ago at the Division of Applied Chemistry of the N.R.C. in Canada, Orzechowski and MacCormack[14] give a fairly complete treatment which in part confirms earlier results of Twigg in England and Shen-Wu Wan in the U.S. but necessitates extension of some earlier ideas. They used a patented catalyst made by leaching a Ca-Ag alloy previously pressed in granular form on to Ag sheets, resulting in a highly porous catalyst with 0.48% Ca. It was found that the catalyst was extremely sensitive to pre-history, and that reproducible kinetic measurements could only be obtained with frequent stabilising checks to maintain the surface in the same reference state. A conditioning period of 150 hr. in ethylene-oxygen mixture at 234°C. was necessary, ascribed to the slow attainment of equilibrium in the oxygen atom positions and with surface poisons. Further, a catalyst conditioned for ethylene oxidation was still in the unsteady state for ethylene oxide oxidation. The kinetic results for ethylene oxidation could be fitted, not to the conventional rate equations, but to one of the form:

$$r_o = \frac{k}{1 + a/p_e + b/p_o}$$

where r_o is the extrapolated initial reaction rate, p_e and p_o are ethylene and oxygen partial pressures, and k, a and b are constants at constant temperature. Figs. 1 and 2 show calculated curves and experimental points for rates of formation of ethylene oxide as a function of reactant partial pressures at 274 and 234°C. respectively. The following generalisations are applicable at 274°C.:

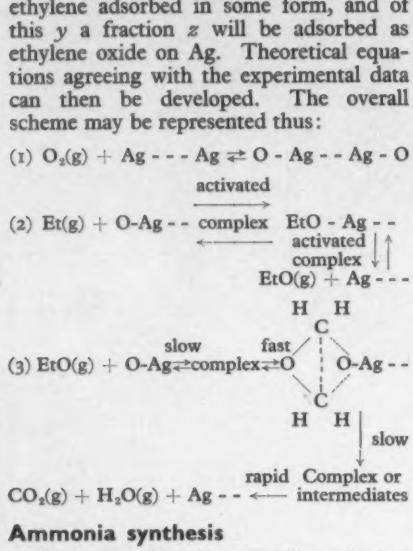
(1) At low constant p_e the rate is high and increases with p_o, the maximum conversion being reached more rapidly, whereas with high p_e both the rate and maximum conversion are lower.

(2) At low constant p_o, the rate and maximum conversion both decrease rapidly with increasing p_e, and this decrease is less at high constant p_o.

However, since the same factors which favoured high conversion to ethylene oxide also favoured oxidation of this to CO_2, they conclude that a high p_o/p_e ratio is not necessarily the best for ethylene oxide production.

The authors contend that in production the conversion of ethylene to CO_2 probably proceeds subsequent to adsorption of ethylene oxide on oxygen-covered Ag,

resulting in an activated complex which then breaks down with desorption of CO_2 and H_2O. Thus at any instance a fraction x of available surface will be covered by oxygen atoms, a fraction y of this will hold ethylene adsorbed in some form, and of this y a fraction z will be adsorbed as ethylene oxide on Ag. Theoretical equations agreeing with the experimental data can then be developed. The overall scheme may be represented thus:


(1) O2(g) + Ag - - - Ag ⇄ O - Ag - - Ag - O
activated
(2) Et(g) + O-Ag - - complex EtO - Ag - -
activated complex
EtO(g) + Ag - - -
(3) EtO(g) + O-Ag ⇄ complex ⇄ O
slow
fast
O-Ag - -
slow
rapid
Complex or intermediates
CO2(g) + H2O(g) + Ag - -

Ammonia synthesis

Neilsen has fully discussed his and other work on promoted iron catalysts (refs. [3, 12] p. 1). Iron, osmium and rhenium, and nitrides of tungsten, molybdenum and uranium are the best known catalysts, but promoted iron catalysts are the most important industrially. While the catalysts are essentially the same as used 40 years ago, it is only relatively recently that their true structure has been elucidated qualitatively; Neilsen envisages no quantitative treatment in the near future because of the complexity of the possible inter-reactions. He considers natural or synthetic magnetites the optimal composition for unreduced catalysts, though this is impossible to maintain in use because of variations in synthesis conditions resulting in changes in stability and activity. Promoters, present in natural magnetites, are essential to maintain activity, and industrially doubly promoted—alkali metal oxide plus stable amphoteric oxide—are better than singly promoted catalysts. He feels that those triply promoted with K_2O-CaO-Al_2O_3 are superior in thermostability during life, the alkaline earth metal entering the magnetite matrix and increasing the amount of other promoters which can also enter.

The catalyst after reduction—as shown by x-ray diffraction, magnetochemical and adsorption investigations—consists of small crystallites with very pure α-iron in the interior and the promoters concentrated in the surface layers (probably as complex aluminate), fairly well distributed so that most iron atoms are near a promoter atom but sufficiently non-uniformly to provide a heterogeneous surface with varying activity (probably because of varying surface work function and electronic properties). That increased activity is not due solely to stabilisation of larger available surface areas, but also to an increased activity per iron site with double promotion, is shown by the following figures for three catalysts in Table 1 (% NH_3 refers to operation at 400°C., 100-atm. pressure and 5,000 space velocity):

Table 1

Cat. No.	Al_2O_3 %	K_2O %	*sq.m./g.*	*sq.m./g. equiv.* Fe	NH_3 %
954	10.2	0.0	13.2	5.1	8.2
931	1.3	1.59	3.72	1.5	12.3
973	0.15	0.0	1	1	3.3

With triply promoted catalysts, the conversion efficiency (% theoretical NH_3) increases with temperature, but the conversion percentage (vol. % NH_3 in exit gases) is maximal at 450°C. The equilibrium percentage of NH_3 and rate of conversion both increase with pressure, but the efficiency decreases slightly. The optimal N_2/H_2 feed ratio is greater than 3, agreeing with the postulate that chemisorption of nitrogen is the rate-determining step. Sulphides act as permanent poisons, while as little as 100 p.p.m. oxygen-containing gases temporarily block the active centres. In general, the triply promoted are more resistant, though slightly less active, than doubly promoted catalysts, but can be operated at 450°C. instead of the usual 400°C. because of their greater thermostability.

Neither nitrides nor hydrides are formed with iron catalysts. Soliman[15] has suggested that ammonia may be synthesised through the intermediary of suitable nitrides and hydrides (for instance of calcium, cerium or lithium) by passing hydrogen and nitrogen alternatively or as a mixture over the heated metals. He considers that, by using high pressures at 300 to 400°C., good yields should be obtainable, providing thermal equilibrium between the gases and ammonia can be established.

Catalytic conversions of CO and H_2 mixtures

As indicated above, in the normal ammonia synthesis the rate-determining step is the chemisorption of N_2. The formation of NH radicals may play some part, but there is no complication with undue nitride formation. Because of the much greater number of possible competing reactions with CO and H_2 over catalysts, it has proved much more difficult to unravel the primary steps in the conversion. Apart from adsorption and compound formation with the substrate, there are the possibilities of formation of water, carbon dioxide, methane, and of hydroxylation, chain growth, hydrogenation, dehydration, isomerisation and cyclisation reactions with intermediates. The ultimate products therefore depend strongly on the nature of the catalysts and on operating conditions. However, recent work is indicating that the primary reactions may well be the same in all cases, and that the differences are again ones of degree.

Industrially, the present emphasis is on the use of cheap iron catalysts operated under conditions such that useful yields of organic chemicals ('oxygenates') rather than solely hydrocarbon fractions can be obtained, contributing materially to the economics of the process. The growth over the past 25 years has been generally reviewed—though primarily from the point of manufacture of gasolines—by Pilcher (ref. [11], p. 271). There have also been surveys of developments in Germany[16, 17] America,[5, 18, 19] Great Britain[25, 28] and Russia (Toplin *et al.*, ref. [12], p. 276); these have covered both plant or pilot-plant

Table 2. Types of Catalysts and Products for CO and H_2 Conversions

Catalyst	*Promoter and support*	*Temp., °C.*	*Pressure, atm.*	*Process*	*Ref.*	*Products (in order)*
Ni, Co	—	150—300	1—2	Gas	11	Methane
Fe	K_2O-Al_2O_3	400	80—200	Synthol	11	Oxygenates
ZnO	—	250—350	80—450	Gas	11	Methanol
ZnO	Alkali	,,	,,	,,	11	Higher alcohols
Co	Cr_2O_3	200	1—2	,,	11	Paraffins, olefines
Fe	ZnO					
Co	ThO_2-MgO kieselguhr	160—200	4—25 (7)	F-T, gas	11, 25	Paraffins, olefines
Fe	K_2O-Al_2O_3	200—300	5—30	German	11	Olefines, paraffins & oxygenates
Ru	—	150—250	80—1,000	,,	11	High m.w.t. paraffins
ThO_2	—	< 400	100—900	*iso*-synthesis	11	*iso*-alcohols
ZnO-Al_2O_3		450	,,			*iso*-paraffins
		475	,,			Naphthenes
		500	,,			Aromatics
Fe (cheap ore)	?	300—350	15—35	Hydrocol fluid	20	Olefines, paraffins & oxygenates
Fe	Cu-K_2O	175—230	10	Fluid	16	Olefines, paraffins & alcohols
Fe	K_2O-MgO	220—270	20—25	,,	18	
Fe	,, (fused)	190—220	20	Synol	19	Olefines and 50% oxygenates
Fe nitrides	,,	190—200	7—30	Fluid	19	Oxygens, paraffins & olefines
Co	ThO_2-MgO kieselguhr	150	4—20	Gas	29	Paraffins, olefines & oxygens
Ni-Cr steel	—	800	10	Gas	21	Methane (low)

design and catalyst preparation and performance.

Table 2 lists some of the more important catalysts, together with operating conditions and nature of the products obtained, more or less in order of their development from the initial work of Sabatier in 1901-2. It should be noted that in only two processes are pure single products obtained—methane over pure Ni or CO at low temperatures and pressures, and methanol over zinc oxide at high temperatures and pressures; in both cases, addition of alkalis to the catalysts cause formation of multi-component products, as does dispersion of Ni or CO on carriers. Pilcher makes the following general points:

(1) Catalysts with higher hydrogenating activities (Ni) can be operated at lower temperatures. Oxides, with low activity, must be used at higher temperatures than metals.

(2) Long contact times favour CO_2 formation, short contact times water formation.

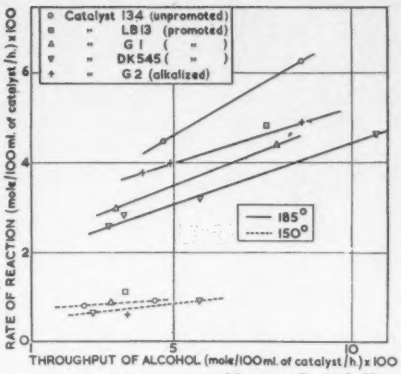
(3) Optimal conditions for gasoline fractions for metal catalysts are close to those where (hydro)carbonyls can be detected.

(4) With oxide catalysts there is primary formation of oxygenated compounds followed by dehydration.

(5) Physical structure of the catalyst, which can be changed by the method of preparation, is of decisive importance.

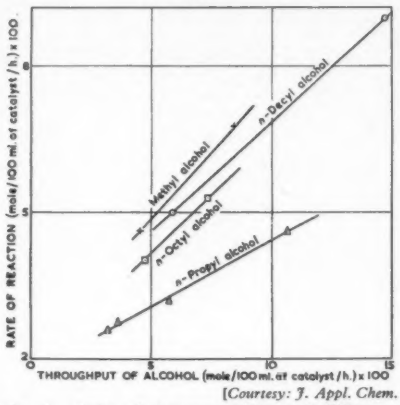
The theory that intermediate carbide formation[5] with metals provides th precursor has now been almost positively disproved by a variety of evidence. Iron carbides formed are stable to hydrogen, although cobalt carbides are not, at the operating temperatures. The increase in alcohol formation with iron catalysts under certain conditions (Table 2) suggests alcohols as precursors. Electron and *x*-ray diffraction studies[23] on used iron catalysts of various types showed good agreement in general; with used catalysts, the evidence suggests surface structures of magnetite (*i.e.* oxidised Fe) with any promoter (*e.g.* MgO) present and no carbide; the bulk structure consists of various carbides usually with some iron. It was noted that the MgO was almost entirely concentrated in surface crystallites, and that the presence of magnetite did not impair the activity or selectivity of the catalyst, suggesting that this might actually be the principal surface phase during synthesis.

Anderson (refs. [19], [12], p. 355) considers that iron nitrides are particularly suited for synthesis of oxygenated compounds. They are very resistant to oxidation and carbon deposition (causing disintegration). Carbides are usually more active than ordinary iron with the same selectivity, and the nitrides and carbonitrides are more active still but with a different selectivity. These have been patented,[22] following a fairly complete study of their chemistry.[12] Compared with the non-nitrided catalyst under similar operating conditions but at 37°C. lower temperature, one with N/Fe ratio 0.46 gave 10 times as much oxy-



[*Courtesy: J. Appl. Chem.*

Fig. 3. Rate of decomposition of n-PrOH as a function of alcohol throughput for different catalysts.[27]


n-Decyl alcohol
Methyl alcohol
n-Octyl alcohol
n-Propyl alcohol
RATE OF REACTION (mole/100 ml. of catalyst/h.) x 100
THROUGHPUT OF ALCOHOL (mole/100 ml. of catalyst/h.) x 100

[*Courtesy: J. Appl. Chem.*

Fig. 4. Rate of decomposition of different alcohols as a function of throughput at 185°C.[27]

compounds (and much less olefines) in the low-boiling fraction and 20 times as much in the higher ones.

Weitkamp[20] has compared the product distribution from normally operated iron and cobalt Fischer-Tropsch catalysts. Iron gives higher yields of C_2 oxygenated compounds, lower C_2 but higher C_3 to C_5 hydrocarbons than cobalt, and both show a characteristic decline in yield thereafter. The oxygenates consist largely of alcohols, aldehydes and ketones. Hall and co-workers[26, 27, 29] have studied not only the product distribution with cobalt catalysts under conditions giving higher yields of oxy-compounds, but also the rates of decomposition of various alcohols over the catalysts under the same conditions when admixed with hydrogen or synthesis gas. Figs. 3 and 4 show their results for the decomposition of alcohols over various catalysts, the rate being expressed as 100*x* mole/100 ml. catalyst/hr. The following conclusions are drawn:

(*a*) The decomposition increases with temperature, with activation energies 23 to 24.1 Kcal., similar to those for the synthesis reaction (24 to 26 Kcal.).

(*b*) Unpromoted catalysts have higher decomposition activity than promoted ones and the presence of alkali further increases this at the higher temperatures.

(*c*) The rate of decomposition falls by about 25% on increasing the pressure from 1 to 11 atm.

(*d*) Catalysts which show a lower activity for synthesis of alcohols (based on % conversion of CO and H_2) tend to give a higher wt. % of alcohols greater than C_5, and also have lower activity for decomposing alcohols. If the activity for oil synthesis is high, a large proportion of the surface is available for other reactions such as alcohol decomposition, resulting in low yields.

(*e*) The absence of *sec-* and *iso*-alcohols in synthesis products cannot be due to their decomposition.

Kummer and Emmett's studies[24] with traces of radioactive alcohols added to the synthesis gas show that with Fe catalysts C_2 to C_4 alcohols, but not CH_3OH, can contribute to the build-up of longer chains. This probably accounts for the relative absence of methanol in the synthesis products.

These recent results have led the various authors to propose basic schemes for both Fe and CO catalysts which involve the following steps:

(*a*) Chemisorption of CO and possibly hydrogen on adjacent sites, followed by electron shifts to give an activated complex, possibly of the type Metal = CHOH.

(*b*) Conversion of CHOH groups to alcohols.

(*c*) Decomposition of alcohols to olefines, etc.

(*d*) Hydrogenation of olefines.

(*e*) Other side reactions.

Thus we have the picture of a number of adsorbates competing for sites on the catalyst surface, which may well vary markedly in activity for the different types of reaction. With this qualitative picture the apparently wide divergence in the behaviour of 'metal' and 'oxide' catalysts narrows. Much more quantitative data on the true nature of the active surfaces of both types and on the reactions actually occurring is required before further material progress can be made.

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STIRRERS

Evaluation of Emulsifying Performance

By K. Magnusson

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Laboratory tests were made to select a stirrer for emulsifying vegetable oil and glycerin in a heated vessel. A single-blade stirrer was found most efficient in achieving both a stable emulsion and good heat transfer. When it is not necessary to achieve both these objectives other types of stirrer may be used with less expenditure of power.

A VEGETABLE oil was to be reacted with glycerin in a vessel of these dimensions: diameter, 240 cm.; height of the cylindrical jacket, 240 cm.; and depth of the hollowed bottom, 50 cm. It was equipped with a double heating coil, the diameter of which was 120 cm. The height of the liquid was the same as the diameter of the vessel. The oil and the glycerin were emulsified by intense stirring which produced a good heat transfer.

A suitable stirrer was selected by experiments carried out in a glass vessel 28 cm. in diameter and equipped with a double heating coil made from a tube having an outer diameter of 1 cm. The inside diameter of the outer coil was 18 cm. and the inside diameter of the inner coil was 15 cm. The vertical space between the coils was 1 cm. and the height of the liquid 28 cm. Except that the bottom of the glass vessel was slightly convex whilst the big vessel had a concave bottom, the glass vessel, including the coil, corresponded geometrically to the big vessel. Instead of a vegetable oil and glycerine, a mixture of 36% by volume of a saturated solution of common salt and of 64% by volume of a mineral oil of a low viscosity was used in the model vessel. At room temperature this mixture had about the same viscosity and density as the oil/glycerin mixture would have at the reaction temperature in the big vessel.

In these experiments the following stirrers were used:

(1) A six-bladed stirrer (diameter (L) of 12.8 cm.). The blades were straight, their length being 4.4 cm. and breadth 2.9 cm., and they could be set at varying angles (φ).

(2) A turbine (L = 15 cm.) with eight vertical and shrouded blades (length 2 cm. and breadth 2 cm.).

(3) A two-bladed propeller (L = 15 cm., pitch 2 cm.).

(4) A one-bladed stirrer (L = 12 cm.), being a rectangular plate of height 9 cm. and breadth 12 cm.

Experimental details

The mixture was stirred for 3 min. and then the emulsion was left for a time—as indicated below—to separate. In each case a determination was made of the stirrer speed and power consumption needed to give an emulsion which would take 20 min. to separate. Preliminary experiments showed that the stirrers had to be placed in such a way that their lower edge reached just to the level of the oil and salt solution interface.

Table I. The One-Bladed Stirrer in a Model Vessel

r.p.m.	*h.p.*	*Ne*	*Re*	*Fr*	*Separating time in min.*
150	0.0029	5.56	720	0.077	2
200	0.0073	5.81	960	0.136	2
240	0.0128	5.90	1152	0.196	7
280	0.0212	6.16	1340	0.266	12
290	0.0236	6.17	1390	0.286	20
300	0.0260	6.16	1440	0.306	20
320	0.0323	6.29	1540	0.348	20

Even at a speed of 775 r.p.m. no stable emulsion was produced by the propeller. The emulsion separated in 2 min. The result was just as bad with the turbine rotating at 410 r.p.m., but at 290 r.p.m. and a power consumption of 0.0235 h.p. the one-bladed stirrer produced an emulsion separating in 20 min. By using the six-bladed stirrer, however, the best results were achieved as follows:

At φ = 90°, 240 r.p.m. and 0.0276 h.p., an emulsion was obtained which separated in 2 min.

At φ = 60°, 315 r.p.m. and 0.0181 h.p., an emulsion was obtained which remained stable for 30 min.

At φ = 45°, 400 r.p.m. and 0.0207 h.p., an emulsion was obtained which remained stable for 30 min.

At φ = 30°, 545 r.p.m. and 0.0267 h.p., an emulsion was obtained which separated in 2 min.

In spite of the fact that the power consumption of the six-bladed stirrer at φ = 45° and at φ = 60° was less than that of the one-bladed stirrer when producing an emulsion separating in 20 min., the one-bladed stirrer was chosen for the additional tests. The reason for this choice was that the one-bladed stirrer proved to cause an even and intense current throughout the whole heating coil, while the six-bladed stirrer caused an intense current only through that part of the coil at the level of the stirrer. As mentioned before, the best possible heat transfer between the coil and the liquid is of great importance, and in this respect also the one-bladed stirrer proved to be better than the six-bladed one. The results of the additional experiments with the one-bladed stirrer are given in Table 1.

From the values giving a very stable emulsion according to the data shown, *viz.* 300 r.p.m. and 0.026 h.p., the necessary number of revolutions and power consumption in the larger vessel were calculated. The difficulties of such a calculation will be seen.

Calculation

The power consumption of a stirrer can be computed from the equation:

$$\mathrm{Ne} = k.\mathrm{Re}^a.\mathrm{Fr}^b \quad \ldots\ldots\ldots (1)$$

where

Ne = Newtonian value = $75.10^5.P.g.60^3/L^5.\gamma.n^3$

Re = Reynold's number = $n.L^2.\gamma/60.\eta$

Fr = Froude's number = $n^2.L/60^2.g$

P = Power consumption in h.p.

g = Gravity acceleration in cm.s^{-2}

L = Stirrer diameter in cm.

n = Stirrer speed in r.p.m.

γ = Density of liquid in g.cm.$^{-3}$, here about 1 g.cm.$^{-3}$

η = Viscosity of liquid in poise, here about 0.5 poise.

a = A constant within certain limits of Re.

b = $(A - \log \mathrm{Re})/B$.

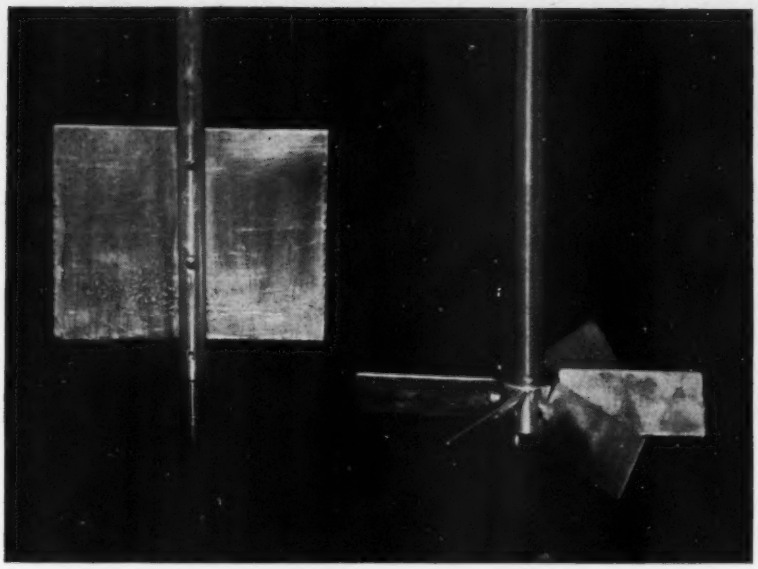
A and B are constants at constant ratios D: L.

k = A constant when a is constant.

By experience we know that a vessel equipped with four vertical baffles $D/10$ broad and fixed to the wall of the vessel is fully baffled. The flow is turbulent. If so, there is no need to take the viscosity effect into consideration, and the equation (1) will be reduced to:

$$\mathrm{Ne} = k_1.\mathrm{Fr}^b \quad \ldots\ldots\ldots (2)$$

A vessel equipped with a double heating coil of the same height as that of the liquid



The one-bladed stirrer and the six-bladed stirrer used in the experiments on the emulsifying performance of various stirrers.

is also considered to be fully baffled. In this case also equation (2) is applicable. The values of the factors k_1 and b are computed from the data of Table 1, giving the following equation:

$$Ne = 6.84.Fr^{+0.08} \quad \ldots\ldots \quad (3)$$

The constant $b = +0.08$ corresponds to a Reynold's number 1440. The constant a can never have a positive value and it is rather exceptional that the value of the constant b is positive. In this case it is due to the fact that the Reynold's number is so small that (A –log Re) becomes positive. With a higher value of the Reynold's number, the value of b will of course be negative.

The experiments shown in Table 1 should have been continued until a proper suction funnel had developed, making it possible to determine the critical stirrer speed. As no suction funnel worth mentioning had developed at 320 r.p.m. and the emulsion obtained at this rate was stable, the experiments were finished at this stirrer speed. When no suction funnel has developed the equation (2) can be reduced to:

$$Ne = \text{constant} = 6.2 \quad \ldots\ldots \quad (4)$$

From Table 1 it will be seen that at a stirrer speed of 280 to 320 r.p.m. Ne = constant = 6.2. It is accepted practice to calculate with a constant value of the Ne number in cases like this.

Büche's equation was used to compute the required stirrer speed in the large vessel as follows:

$$n_2 = n_1.(1/m)^{2.3} \quad \ldots\ldots\ldots \quad (5)$$

which is applicable to turbulent flow and in which

n_1 = The suitable stirrer speed (300 r.p.m.) found in the model vessel.

n_2 = The stirrer speed needed in the large vessel.

m = The factor of scaling up = $D_2 : D_1$ = 240 : 28 = 8.6.

According to equation (5), n_2 = 72 r.p.m. and, as a consequence, 75 r.p.m. was chosen as a suitable stirrer speed in the larger vessel. The power consumption P = 16.5 h.p.—corresponding to this stirrer speed—was found with the assistance of equation (4).

Plant trials

The larger vessel was equipped with a motor of 25 h.p. and with a one-bladed stirrer, the blade being 100 cm. broad and 75 cm. high. The vessel was then filled with water to the height of 240 cm. for stirrer tests. At 75 r.p.m., however, the power consumption was 23 h.p. instead of 16.5 h.p., or 40% more than that calculated above. The greater power consumption in itself was not very significant, but at the speed of 75 r.p.m. a suction funnel developed which reached down nearly to the stirrer blade. The suction funnel depth had to be reduced to at least half its size. In another paper[1] it has been proved that the suction funnel depth is directly proportional to the power consumption. Thus a reduction of 50% of the power consumption had to be made in order to reduce the depth of the suction funnel by one-half. To achieve this the stirrer speed had to be slowed down to n = 60 r.p.m., for $(n : 75)^3 = 0.5$. On slowing down the stirrer speed to 60 r.p.m., the power consumption was reduced to 12.5 h.p. and the suction funnel was about half as deep as that developed at 75 r.p.m. The results of these two tests carried out in the larger vessel are given in Table 2.

Table 2. The One-Bladed Stirrer in the Large Vessel

r.p.m.	*h.p.*	*Ne*	*Re*	*Fr*
60	12.5	9.2	1,000,000	0.102
75	23	8.7	1,250,000	0.159

The two results stated in Table 2 give an equation different from the equation (3), or

$$Ne = 6.75\ Fr^{-0.135} \quad \ldots\ldots\ldots \quad (6)$$

In order to be able to use equation (2) for calculating the power required in the larger vessel, the constants A and B in the formula $b = (A - \log Re)/B$ must be determined. This is done by tests in a pilot plant. If the results in Table 1 are compared with the results in Table 2, then $b = (4.24 - \log Re)/13.4$. This value of the index b of Froude's number gives the following equation:

$$Ne = 6.8\ Fr^{(4.24\ -\ \log Re)/13.4} \quad \ldots\ldots \quad (7)$$

From this equation the power required in the big vessel at 60 and 75 r.p.m. is 12.5 and 23.5 h.p., respectively, which is in agreement with the values of 12.5 and 23 h.p. established through the experiments.

During the experiments in the large vessel the total power consumption—that is, the power consumption of the stirrer plus the power losses in motor, ball-bearings and packing box—was determined. During the experiments in the model vessel, on the other hand, only the power consumption of the stirrer was determined. As the power losses in the motor, ball-bearings and packing box of the technical vessel probably amounted to 1 to 2 h.p., the agreement is very good between the power consumption determined from equation (3) and the consumption experimentally established.

A curious observation made during the model experiments ought to be mentioned. The oil in the larger vessel was to be protected by a layer of carbonic acid blown into the vessel. The blowing of carbonic acid below the stirrer of the model vessel had the unexpected effect of reducing the separating time of the emulsion from 20-30 min. to only 2 min. Only when the mixture of liquids had been left long enough for all the gas bubbles to disappear, could a stable emulsion be obtained. When carbonic acid was blown into the vessel above the level of the liquid, however, no unfavourable effects on the emulsifying process could be detected.

Summary

The one-bladed stirrer is particularly suitable for achieving simultaneously a stable emulsion and a good heat transfer between the emulsion and a cooling or heating coil of a vessel. If it is only necessary to produce a stable emulsion, this will be achieved with less power consumption by a six-bladed stirrer with the blades set at an angle of 45 to 60° to the horizontal. If it is not necessary to achieve excellent mixing but only good heat transfer between

a liquid and a cooling or heating coil, this will be achieved with less power consumption by substituting an anchor stirrer equipped with two to four narrow vertical blades passing as close as possible to the coil. The anchor stirrer gives as good a heat transfer as the one-bladed stirrer with one-third the consumption of power. The results achieved with this special anchor stirrer will be reported in a separate paper.

When calculating the power consumption of a stirrer in a technical vessel on the basis of values experimentally obtained in a model vessel, it is necessary to take the higher arithmetical value of the Froude number for the production vessel into consideration, for this higher value means that, even if the Newtonian value was found to be a constant in the model vessel, this value is not constant in the production vessel but is a function of the Froude number.

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New Petroleum Catalyst Plant in Holland

By John Grindrod

A NEW plant for the production of synthetic micro-spheroidal fluid cracking catalyst for the oil industry has been brought into production by Koninklijke Zwavelzuurfabrieken v/h Ketjen N.V. at Amsterdam. It will manufacture the catalyst using the processes of the American Cyanamid Co., New York, and is claimed to be the first factory of its kind on the Continent.

Still a somewhat new and rapidly expanding technique in the petroleum industry, fluid catalytic cracking of mineral oil (in which the catalyst is mixed with the oil and pumped around as part of it) will in the future demand increasing quantities of the catalyst, and Ketjen is anticipating being able to supply a number of cat-crackers which are now under construction or planned in various parts of the world.

The product of the new factory is intended, in particular, for the European refineries of Standard Oil and the Royal Dutch/Shell Group. The management has already decided to double the capacity of the factory during 1954.

For the Ketjen concern the manufacturing of an oil cracking catalyst is quite a new venture. Established in 1835, the firm has concentrated chiefly on making sulphuric acid, though other products have been made from time to time. In 1935, however, its field of activities was broadened. The production of activated carbon was begun and an invention concerning ion exchangers signalled the start of extensive work on these products. A plant for making saccharin was built and completed just before the war and a series of by-products from this plant brought on to the market. The scarcity of potassium permanganate, necessary for the making of saccharin, induced Ketjen to build a large and modern plant for the production of this chemical. Other items, such as liquid sulphur dioxide and chloramine, were also added to the manufacturing list, while a modern research laboratory was put into use in 1951.

Built on 162 reinforced concrete piles, each 78 ft. in length, the new catalyst plant has been equipped by a number of well-known Dutch firms. Process and project engineering was in the hands of the Ketjen engineering department with know-how supplied by American Cyanamid; construction and engineering contracting was by Werkspoor, Amsterdam; electric equipment by Heemaf, Hengelo; filter system by Dorr Oliver, Amsterdam; instrument engineering contracting by Groeneveld and van der Poll, Amsterdam; wooden process tanks by Chemical Works Vondelingenplaat, Vlaardingen; spray drier furnace by Chamotte Unie, Geldermalsen; dust collecting system by Hartmann, Offenbach, Germany, and water-treatment plant by Duper Waterreiniging, Amsterdam.

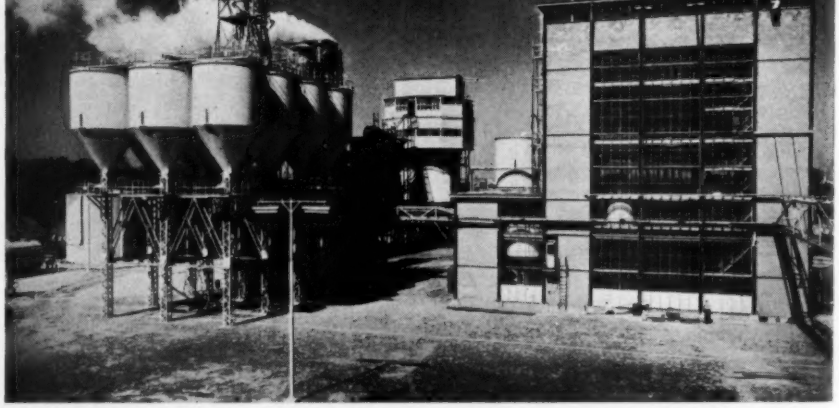
The type of 'fluid' catalyst to be made by Ketjen consists of an extremely fine white powder, each particle being a minuscule ball. The particles are light in weight and so small that the material runs like water, especially when mixed with gases or air. Chemically an alumina silica compound, the main raw materials used at the Ketjen plant are:

(1) *Sodium silicate*, which comes from two Dutch factories in solid form and is dissolved in a special plant which was built by one of these factories near the Ketjen works.
(2) *Aluminium hydroxide*, which is imported as such.
(3) *Ammonia*, which comes from the Mekog at Ijmuiden, Holland.
(4) *Sulphuric acid* from Ketjen's own works.
(5) *Water*, which is pretreated in a plant designed by Ketjen's subsidiary, Duper Waterreiniging N.V., and containing Ketjen's own ion-exchanging material, *Dusarit S*.
(6) *Fuel oil* bought from the oil companies.

The sodium silicate is treated with sulphuric acid to form a gel. This gel is then treated with aluminium hydroxide and ammonia, the resulting product being carefully and repeatedly filtered and washed so as to purge it of all impurities.

After the cleansing and filtering processes the aluminium-silica gel is pumped to an oil-fired drying tower, where the material is sprayed, either by means of a spinning disc rotating at a speed up to 12,000 revolutions per minute, or by nozzles. Each sprayed drop of the gel dries as a small round particle of a size between 20 and 150 thousandths of a millimeter. The finished product is extracted from the drier gas stream, collected in hoppers and packed in bags or directly transported in bulk by tank trailer to the oil refineries.

At the Ketjen plant the preparation of the gel and the washing is done indoors in the wet process building. The drying, collecting and storage equipment has been erected in the open air. Located near to the latter equipment are various storage tanks for the raw materials and the fuel oil for heating the spray drier.



The Amsterdam plant for the manufacture of synthetic micro-spheroidal fluid cracking catalyst. Preparation of the gel and the filtering and washing are done indoors, while the outdoor facilities include drying, collecting and storage equipment along with various storage tanks for raw materials.

Turbo-Machinery for Compressing Air and Gases

By A. Flindle, A.M.C.T.

*The chemical and allied industries, including oil refining and petroleum chemicals, are among the main users of turbo-machinery for air and gas compression. Here the author gives a general survey of the design, construction and application of turbo-blowers and compressors without dwelling unduly on the theoretical aspects of the subject.**

Fundamental principles of gas compression

Adiabatic compression. This is compression without either receiving heat from or rejecting heat to any external source, *i.e.* compression in a heat-insulated system. The increased energy in the air or gas after compression is theoretically equal to the mechanical work done during compression. Moreover, the entropy H/T remains unchanged. An air-cooled heat-insulated blower or compressor is an example of approximately adiabatic compression where pV^n = a constant; $n = Cp/Cv = 1.4$ (see Fig. 1, curve AB).

Polytropic compression. In actual practice a blower or compressor is subjected to internal hydrodynamic losses owing to friction and turbulence through the impeller and diffuser passages, etc. Such losses, together with disc friction, reappear as heat energy in the air or gas discharged from the machine. The effect of this is to modify slightly the compression stage by increasing the value of the exponent n to some value k so that pV^k = a constant (see Fig. 1, curve AC). This has the effect of increasing the specific volume at the compressor discharge. Such a compression stage is called polytropic, *i.e.* compression with hydrodynamic losses in a heat-insulated system.

Isothermal compression. This is compression at theoretically constant temperature throughout the stage. Since there is no change in temperature there is no work done on the air or gas itself. For multi-stage intercooled compressors, the overall compression follows approximately the isothermal law $PV = RT$, where R is the universal gas constant. This, of course, is Boyle's law, since T is constant and therefore PV is constant. The gas equation $PV = RT$ holds exactly for perfect gases, and very nearly for all permanent gases under average conditions except for very high pressures and low temperatures, where some gases begin to become vapours or are subject to condensation. Fig. 2 shows the effect of interstage cooling in multi-stage compressors by the use of intercoolers.

B.S. classification of turbo-machinery

Fans. For large volumes and low pressures from a few inches of water to 1 p.s.i.

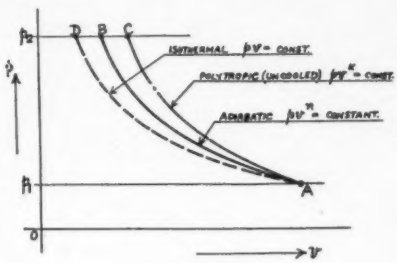


Fig. 1.

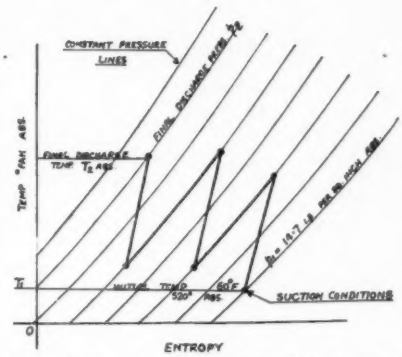


Fig. 2. Effect of interstage cooling by intercoolers.

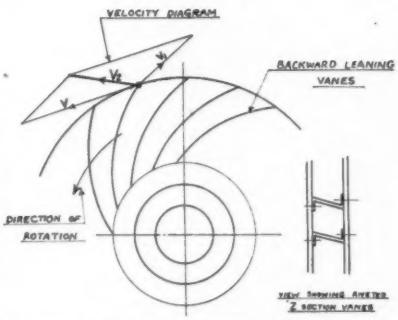


Fig. 3. Action and construction of typical impeller.

Usually run at relatively low speeds with impellers and casings built up of sheet metal.

Blowers or turbo-blowers. For compressing air or gas up to a final pressure not exceeding 35 p.s.i. gauge. No water cooling is applied, since the added expense of a cooling system is not justified in view of the small gain which would be achieved at these pressures. Moreover, in the case of a blast furnace, the increased temperature of the air owing to compression is an advantage. Blowers are sometimes known as:

Exhausters. In practice the removal of gases from a coke oven is an example.

Boosters or circulators. An example is the forced circulation of gases through chemical processes.

Compressors or turbo-compressors. For compressing air or gases up to pressures exceeding 35 p.s.i. gauge and invariably water cooled. The term is usually applied to multi-stage machines irrespective of final discharge pressures. Although large turbo-compressors have been built in this country for final discharge pressures exceeding 100 p.s.i. gauge, reciprocating compressors are usually applicable to this field, although turbo-machines are built for pressures up to 900 p.s.i. and a maximum suction volume of 4,000 cu.ft./min. when running at about 12,000 r.p.m.

The impeller

Apart from the open type, the type of impeller which is generally used for turbo-blowers and compressors is as shown in Fig. 3. This consists of two separate shrouds between which are attached several vanes either straight or curved and usually in the form of a 'Z' section and riveted in position to each shroud as shown.

Air or gas enters the eye of the impeller with a velocity of about 175 ft./sec., is turned at right-angles into the passages formed by the vanes and leaves the periphery of the impeller with some relative velocity V_2 depending on the quantity of air or gas discharged and the peripheral speed of the impeller.

It is generally found that the ideal number of vanes for the average size of impeller to give optimum hydrodynamic efficiency at duty point is 30. Any increase in this number will certainly reduce circulatory flow and turbulence in the passages, but at the same time increase fric-

*This article is the substance of a paper read before the North Staffs. Branch of the Association of Mining, Electrical and Mechanical Engineers. It was published in the *Mining, Electrical and Mechanical Engineer*, 1954, **34** (400), and is reprinted by permission of the Association.

tional losses, whilst a reduction of the number of vanes will have the opposite effect. One compromise arrangement which is adopted is to add short intermediate vanes.

Characteristic. With backward-bending vanes, as indicated in Fig. 3, the pressure/volume characteristic will be as shown in Fig. 4, *i.e.* the discharge pressure will decrease gradually with increasing volumes. Thus at designed inlet pressure and temperature it is not possible to overload the impeller, since the discharge pressure and brake-horsepower will decrease at an appreciable rate if the volume at suction increases beyond 120% of the designed volume.

Stability. Stability is measured as the percentage ratio of change of volume between normal design volume and surge point to normal design volume; this has a value of approximately 65% for compressors developing very low pressure ratios to as low as 30% for compressors developing high pressure ratios.

Provision can be made for high stability at reduced efficiency if partial loading is sustained for long periods; but if the design loading is maintained for most of the time, improved efficiency can be obtained only at the expense of stability.

Head as function of peripheral speed. The head which can be developed by a compressor stage, consisting of impeller and diffuser, can be expressed as

$$H = \mu \frac{V^2}{g}$$

where μ = Pressure coefficient;
V = Peripheral velocity of impeller, ft./sec.;
g = Gravitational constant = 32.2 sq.ft./sec.

An average value of μ for a multi-stage compressor is of the order of 0.55 and, with a normal peripheral velocity of 780 ft./sec., it will be found that the head per impeller or stage is approximately 10,080 ft.

The capacity of the impeller will therefore be 10,080 ft.lb. per lb. of air or gas. This is related to power required for a given duty as discussed in a later section.

Specific speed. Specific speed is the term used for classification of impellers based on their performance and proportions. It is a function of the impeller proportions and is therefore constant for a series of impellers having the same angles and proportions.

Specific speed N_s is defined as the speed in revolutions per minute at which an impeller would operate if reduced proportionately in size so as to deliver a rated capacity of 1 cu.ft./min. against a total static head of 1 ft. calculated on an adiabatic basis.

$N_s = \frac{(\text{r.p.m.})\sqrt{Q}}{H^{\frac{3}{4}}}$ is the specific speed of an impeller delivering Q cu.ft./min. against a head of H ft.

Although the specific speed equation is frequently used in connection with centrifugal pumps, it has not been used to any great extent for blowers and compressors. The author believes, however, that considerably more use could be made of the specific speed equation for turbo-blowers and compressors, with obvious advantage.

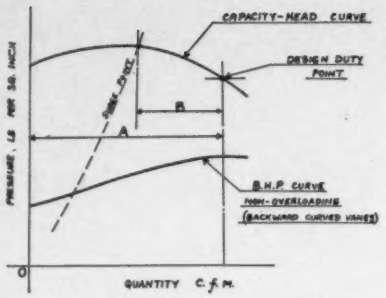


Fig. 4. Pressure/volume characteristics of impeller.
Impeller stability = B/A.

The diffuser

The diffuser is used to transform the kinetic energy of the air or gas leaving the impeller to pressure energy with the minimum amount of loss. The majority of blowers are fitted with diffusers without vanes and of the volute type, exactly as for a low-head centrifugal pump.

For high pressures, however, involving multi-stage machines and where space is important, vane-type diffusers are used (see Fig. 5, which also shows the arrangement of the diffuser relative to the impeller).

The sizes of volute or diffuser passages are calculated on the basis of quantity of air or gas discharged related to change in specific volume, as the kinetic energy of the gas leaving the impeller is transformed into pressure energy during its passage through the volute or diffuser.

Multi-stage operation

As the pressure per stage in a turbo-compressor is limited for practical and commercial reasons, it is frequently necessary to employ machines sometimes with as many as 12 stages in series to obtain the desired discharge pressure. Fig. 11 shows a typical multi-stage turbo-compressor fitted with diffusers.

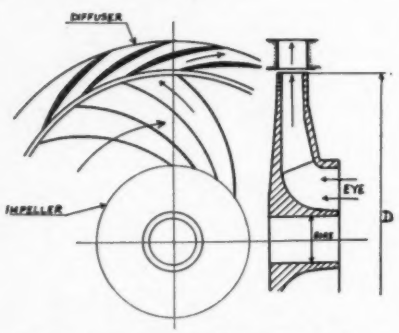


Fig. 5. Arrangement of diffuser relative to impeller.

Unlike a multi-stage centrifugal pump, all the impellers of which are usually identical in size, it will be observed that the impellers in a multi-stage compressor progressively decrease in diameter or width or both from the suction end to the discharge end. This is, of course, due to the compressibility of the air or gas. In a multi-stage compressor there is a substantial amount of accumulated end-thrust due to the unbalanced axial forces on each impeller, and this end-thrust is usually taken care of by a balance piston together with a Michell thrust bearing.

By an arrangement of back-to-back impellers, however, the end-thrust can be virtually eliminated, but only at the expense of a larger machine, *i.e.* with increased bearing centres. This introduces design problems together with the problem of critical speed unless the shaft diameter is increased, with a corresponding increase in impeller-eye diameter. Under these conditions, however, the hydrodynamic efficiency of the compressor will be reduced. For these reasons the back-to-back arrangement is seldom used.

Surging

If the quantity of air or gas absorbed in the system is less than the quantity corresponding to the highest point on the characteristic curve of the blower or compressor supplying the system, unstable conditions will occur. The blower performance will alternate between the delivery of large quantities and shut-off or closed-valve conditions, a very undesirable feature.

The surge point of blowers or compressors usually occurs at approximately 35 to 70% of the normal design flow conditions, depending on the final discharge pressure conditions.

Surging may be reduced by throttling the blower suction by a manually operated device, or by means of an oil-relay mechanism controlled by a diaphragm connected in the discharge line.

A study of Fig. 6 will show that, by throttling the blower discharge to a quantity Q_B corresponding to the point B of maximum head H_B on the unstable blower or compressor characteristic, a new system characteristic OB is created by additional resistance in the throttle valve. If the quantity demanded by the system is now less than Q_B, the blower head will be lower than the pressure in the system and there will be an immediate tendency for the flow to reverse with the operating point moving from B to A.

As the flow is reduced, however, the pressure in the system begins to drop and the blower will again commence to discharge into the system until the pressure is built up to H_B. Head capacity surges between A to some point beyond B then occur, owing to the compressibility of the air or gas which serves as the elastic member in the system.

It is felt that, despite the inherent design features of a turbo-blower or compressor

which appear to militate against the production of an absolutely stable characteristic, some preconsidered revolutionary changes in the design of impellers, volutes and diffusers may well provide for a characteristic that is sensibly stable.

Whilst it is possible to provide a stable characteristic with a multi-stage centrifugal pump because water is for all practical purposes incompressible, the problem with the turbo-compressor is made difficult by the fact that air or gas is compressible and changes its density rapidly during its progress through each stage of compression.

Power requirements

Adiabatic horsepower. Uncooled turbo-blowers or single stages of multi-stage turbo-compressors of the intercooler type can be compared on a basis of adiabatic compression, *i.e.* compression during which no heat is added or extracted from the air or gas during compression (friction and eddy losses neglected).

This means that the compression curve conforms to the equation pV^n = constant and the adiabatic air horsepower is obtained from the expression:

$$\text{h.p.}_a = \frac{144p_1 \times \frac{nV}{n-1}\left[\frac{p_2}{p_1}^{\frac{n-1}{n}} - 1\right]}{33{,}000}$$

p_2/p_1 = compression ratio

where p_1 and p_2 are the initial and discharge pressures in p.s.i. absolute;

V = Inlet volume of air or gas (cu.ft./min.);

$n = \frac{C_p}{C_v}$ = ratio of specific heats.

Isothermal horsepower. The total work done in compressing air or gas in a turbo-compressor depends on changes in specific volume and therefore temperature, so that in order to reduce the work of compression the air or gas is progressively cooled as it proceeds through the compressor. Such compression is called isothermal or compression at constant temperature and follows the equation:

pV = constant (which is Boyle's law).

Isothermal horsepower can now be calculated from the expression:

$$\text{h.p.}_i = \frac{144\ p_1\ V \log_e \frac{p_2}{p_1}}{33{,}000}$$

Fig. 7 shows comparative curves of adiabatic and isothermal horsepower for a given volume of free air at varying percentage discharge pressures. A study of these curves shows that the ideal compression is isothermal, *i.e.* at constant temperature, since under these conditions minimum power is absorbed.

Internal losses

The hydrodynamic losses in turbo-machinery can be summarised as follows:

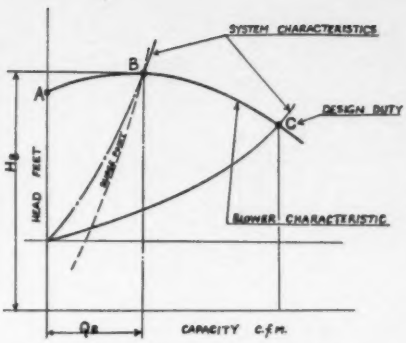


Fig. 6. Head/capacity characteristics.

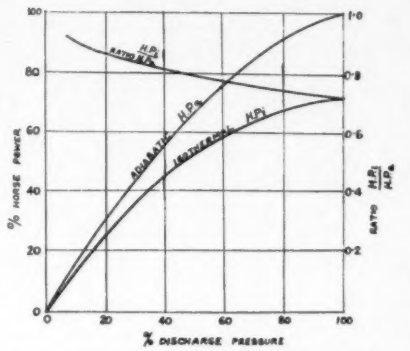


Fig. 7. Comparative curves of adiabatic and isothermal horsepowers.

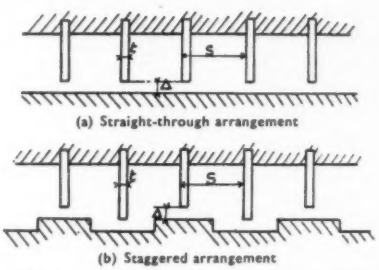


Fig. 8. Labyrinth gland arrangements

(1) Friction and turbulence in eye of impellers;
(2) Turbulence at inlet to impeller vanes;
(3) Friction and turbulence in impeller passages;
(4) Friction and turbulence between impeller outlet and inlet to diffusers;
(5) Friction and turbulence in diffusers or volute passages;
(6) Friction and turbulence in discharge passages.

It is practically impossible to evaluate accurate values of these losses by any known formulae, so that it becomes necessary to use overall loss coefficients when designing passages in the impellers and diffusers, etc.

Between the impeller outlet and diffuser inlet the losses will be high because of turbulence, and the subsequent slowing up of a gas in the diffusers, during which conversion takes place from kinetic to pressure energy, is also a relatively inefficient process.

Only about 45 to 55% of the pressure head available at the impeller outlet will be available as pressure energy, owing to the aforementioned losses.

In addition to the hydrodynamic losses, the following losses must be taken into account:

(1) Disc friction (internal loss);
(2) Bearing and gland friction (external loss);
(3) Power required to drive oil pump and governor (external loss).

Reasonably close estimates of these losses can be obtained from established formulae in any first-class textbook on the design of turbo-machinery.

Actually the mechanical losses are relatively small and the mechanical efficiency can be taken as 0.95 to 0.98 depending on the size of machine.

Glands and seals

Labyrinth gland for preventing inter-stage leakage. Two types of labyrinth gland are in commercial use, namely the straight-through type (Fig. 8 (*a*)) and the staggered type (Fig. 8 (*b*)). Leakage through the labyrinths will depend on a number of factors and can be calculated from the general equation:

$$q = A\alpha\beta\gamma\sqrt{g\frac{P_1}{V_1}}\ \text{lb./sec.}$$

A = Leakage area, sq. ft. $= \frac{\pi D \triangle}{144}$

$\triangle$ = Radial clearance, inches.

α = Contraction factor due to throttling.

β = Overall pressure ratio across labyrinths (depends on number of throttlings, see Fig. 8).

γ = Carry-over correction factor—unity for staggered-type labyrinths.

g = Acceleration due to gravity = 32.2 sq.ft./sec.

P_1 = Absolute pressure before labyrinth, lb./sq.ft.

V_1 = Specific volume before labyrinth, cu.ft./lb.

Shaft seals. Continuous satisfactory operation of high-pressure compressors is dependent on the effectiveness of shaft seals to prevent leakage of air or gas and various types of seal are in use:

Oil seal. This operates on the pressure liquid film principle with no metal-to-metal contact, thus generating little heat; it is adaptable to either low- or high-pressure, high-speed sealing applications. Pressure oil can be supplied from an oil pump driven from the compressor shaft or from an external motor or turbine-driven oil pump.

Contact-type seal. This type of seal provides maximum tightness when operated fully flooded by a suitable cooling medium, but more frictional heat is generated and therefore rubbing speeds are limited. Can be satisfactorily

applied for pressures up to about 120 p.s.i.

Mechanical seal. A paper on this type of seal and its wide range of application was given by Dr. F. B. Porges at Manchester College of Technology on Jan. 30, 1952.

Carbon ring seal. In conjunction with one or two labyrinth fins an arrangement of one or more carbon rings provides a restrictive type of seal which is effective up to pressures of about 50 p.s.i. An insurance against sudden failure is a most important point in its favour.

Governing and governor gear

To do justice to this interesting subject would take up considerable space, so that it will only be possible to discuss briefly the general principles of governing as applied to turbo-blowers and compressors and the need for it.

Constant-pressure regulation. The principal methods of regulation control the suction side or the discharge side depending on the type of turbo-machinery installed. For instance, with an exhauster, constant vacuum in the suction line is essential for satisfactory operation and this is termed constant-pressure regulation.

The control gear consists of a sensitive diaphragm-operated oil governor controlling the admission of steam to the turbine if turbine drive is provided, or a butterfly valve in the suction line if the speed of the exhauster is fixed as with an a.c. motor drive. An arrangement of such gear is shown diagrammatically in Fig. 9.

This type of gear can also be used to control the discharge pressure of blowers.

When the blower or compressor is turbine-driven an alternative type of gear can be used to control the steam supply to the turbine with the object of maintaining a constant blower or compressor discharge pressure. A diagrammatic arrangement of this gear is shown in Fig. 10.

Constant volume regulation. In order to maintain uniform combustion conditions in a blast furnace, for example, the blower should deliver a constant volume of weight of air and one method of achieving this with an a.c.-motor-driven blower is by using a kilowatt meter graduated in cubic feet of standard air per minute. The quantity of air delivered can be read directly and adjusted to the required value by manual means or by automatic electrical relay mechanisms to operate a blast gate through a small electric motor. This gear functions on the basis of brake-horsepower being directly proportional to the product of weight of air discharged and head developed. As the head is constant at constant speed, the weight of air discharged is directly proportional to kilowatt input to the motor.

Movable diffuser vanes. Another method of regulation is by the use of movable diffuser vanes. The vanes are pivoted individually and move together, thus altering the inlet angle and area.

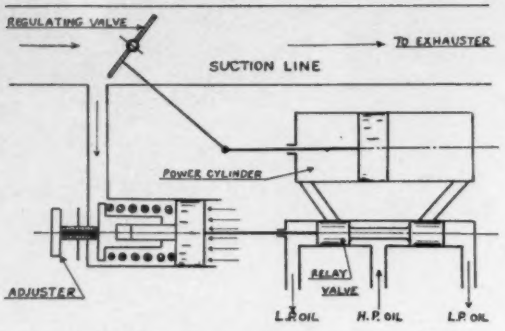


Fig. 9. Arrangement of constant pressure regulator (by throttling).

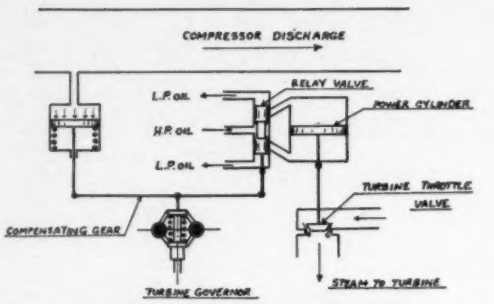


Fig. 10. Arrangement of constant pressure regulator (by speed control).

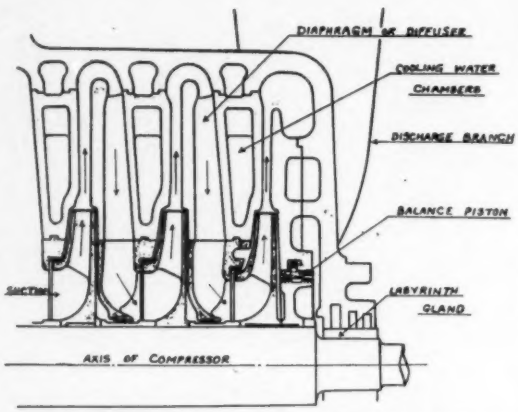


Fig. 11. Part section of multi-stage turbo-compressor showing diffusers and provision for jacket cooling.

The effect of this type of regulation is to move the surge point to the left or towards zero output when the machine is operating at reduced quantities and speeds, thus giving improved performance over a wider range of outputs. There are other methods of regulation, but those already described are typical of the principal methods in general use.

Interstage cooling

Air or gas passing through a compressor can be cooled by two methods: (*a*) water jacketing (usually limited to machines of approximately 15,000 cu.ft./min. capacity); and (*b*) external coolers between the stages or intercoolers.

The first method forms a compact and symmetrical arrangement as shown in Fig. 11; but, owing to the presence of impurities in the cooling water, the water passages may become silted up, when the effective heat transfer through the walls is reduced.

Moreover, the passages are very difficult to clean owing to their inaccessibility. To alleviate the trouble due to silting up, a water-to-water heat exchanger is frequently used to purify the cooling water before entering the jackets. It will be observed that, with jacket cooling, each individual stage is cooled.

The other method of cooling by the use of intercoolers is far more efficient because of improved heat transfer, and is now generally adopted in practice. This arrangement consists of nests of vertical tubes through which the cooling water is circulated and round which the hot air passes before cooling.

The tube nests are easily removable for cleaning without disturbing the compressor unit itself (see Fig. 12). Some multi-stage compressors may have two or more stages of cooling, depending on final discharge pressure and temperature conditions.

The cost of installing and operating a cooling system must be set off against the power saving due to cooling, for any particular installation, when determining the economics of plant operation.

The effect of cooling the air or gas during its progress through the compressor can be shown conveniently on the pV diagram as well as on the temperature/entropy diagram (see Fig. 13).

Table 1 gives approximate quantities of cooling water required for various sizes of multi-stage turbo-compressors for air as a general guide.

Selection of turbo-machinery

Some of the main industrial applications for turbo-blowers or -compressors are:

(1) Cracker blower service for oil refinery installations (residual gases, ethane, methane, etc.).
(2) Blast furnace and cupola blowers, municipal gas plant, blowers, etc.
(3) Gas exhausters for coke plant, etc.
(4) Air circulators in chemical processes.
(5) Compressors for vapour recovery duty in oil refinery installations.
(6) Air compressors for petro-chemical applications (gas separation plant).
(7) Compressors for propane refrigeration service.

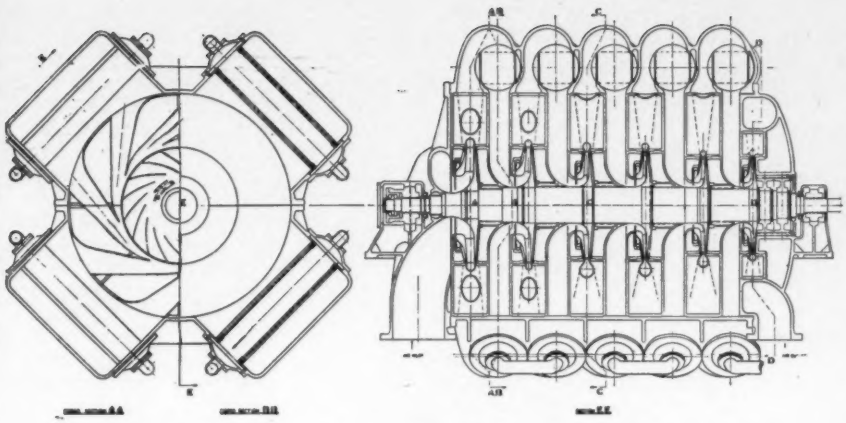


Fig. 12. Sectional view of compressor incorporating Oerlikon diffuser.

(8) Air compressors for the mining industry.

In any enquiry for turbo-compressing plant, the customer usually supplies the discharge pressure, temperature and output conditions required for a particular application and states whether the blower or compressor is to be driven by steam turbine, electric motor or some other prime mover. A selection is then made of a suitable machine from a standard range if possible, and the number of stages determined, together with the approximate power input required.

For an uncooled turbo-blower with a small compression ratio the air or gas horsepower is calculated on the basis of adiabatic compression, whilst for a high-pressure turbo-compressor with inter-coolers the horsepower is calculated on the basis of isothermal compression.

Calculation of performance. The following example will indicate the general procedure for calculating approximate performance figures:

Turbo-blower driven by steam turbine at 5,000 r.p.m. to deal with 20,000 cu.ft./min. of air at 60°F. and 14.7 p.s.i. absolute. Discharge pressure, 16 p.s.i. gauge.

$$\text{Compression ratio } \frac{P_2}{P_1} = \frac{16 + 14.7}{14.7} = 2.09$$

Total adiabatic head or work done per lb. of air

$$H_a = \frac{144 P_1 V_1}{\frac{n-1}{n}} \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] \text{ft.}$$

$$n = 1.4$$

$$\frac{n-1}{n} = 0.283$$

$$\therefore \quad H_a = \frac{RT_1}{0.283} \left(2.09^{0.283} - 1\right)$$

since $144\, P_1 V_1 = RT_1$

$T_1 = 520$°F. abs. (initial temperature).

$R = 53.34$ gas constant.

$$i.e.\ H_a = \frac{53.34 \times 520}{0.283} (1.232 - 1) = 22{,}700 \text{ ft.}$$

Here we should use a three-stage machine developing 7,560 ft. head per stage H. With a pressure coefficient $\mu = 0.55$ this gives an impeller peripheral velocity of:

$$v = \sqrt{\frac{7{,}560 \times 32.2}{0.55}} = 664 \text{ ft./sec.}$$

since $$H = \mu \frac{v^2}{g}$$

and since $$v = \frac{DN}{229}$$

where D = Impeller diameter (inches)

N = Revolutions per minute

$$D = \frac{229v}{N} = \frac{229 \times 664}{5{,}000} = 30.5 \text{ in.}$$

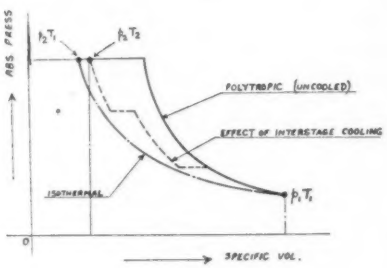


Fig. 13.

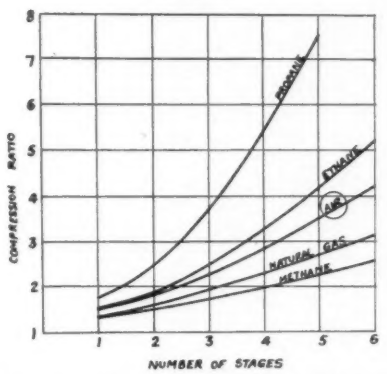


Fig. 14. Uncooled turbo-compression of gases

Suction conditions: 14.7 p.s.i. absolute

Table I. Compressor Discharge Pressure, 100 p.s.i.g. Cooling Water Inlet Temperature, 70°F.

Suction capacity, cu. ft./min.	*Approx. operating speed, r.p.m.*	*Approx. quantity of cooling water required for final outlet air temperature of 80°F. gal./min.*
4,000	7,000	270
6,000	6,000	360
8,000	5,000	500
10,000	5,000	720
15,000	4,000	950
20,000	4,000	1,370

Now the specific weight of air

$$\gamma = \frac{P_1}{RT_1} = \frac{144 \times 14.7}{53.34 \times 520} = 0.0763 \text{ lb./cu.ft.}$$

Weight flow

$$w = \frac{Q\gamma}{60} = \frac{20{,}000 \times 0.0763}{60} = 2.54 \text{ lb./sec.}$$

$\therefore$ Adiabatic air h.p. per stage =

$$\frac{W \times H}{550} = \frac{25.4 \times 7{,}560}{550} = 348 \text{ h.p.}$$

Total air h.p. $= 3 \times 348 = 1{,}044$ h.p. If we now assume a polytropic efficiency of 65% and a mechanical efficiency of 0.95, the horsepower required to be developed by the steam turbine will be:

$$\text{h.p.}_t = \frac{1{,}044}{0.65 \times 0.95} = 1{,}690, \text{ say } 1{,}800$$

h.p. turbine, allowing for a small overload capacity.

In order to arrive at an approximate figure for the discharge temperature of the air T_2 we can assume adiabatic conditions through the blower so that:

$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{0.283} = 520 \times 1.232$$

$$= 640°\text{F.abs.}$$

This actually neglects hydrodynamic losses in the impeller which will tend to increase this temperature slightly.

It is quite impossible to consider in this paper the hydrodynamic performance in any single impeller and diffuser, which of course is necessary to determine the ideal number of vanes and vane angles, etc.

A proper technical approach to the subject and a good knowledge of thermodynamics is essential before any attempt is made to handle such design problems associated with turbo-machinery. All these problems have to be fully considered before determining a standard range of frame sizes for turbo-machinery to give the most favourable average performance figures.

Prime movers for turbo-machinery

In considering the relative merits of different prime movers for driving turbo-machinery, selection should be determined primarily by the following factors: water requirements, operating speed, reliability, process steam supply, electrical supply,

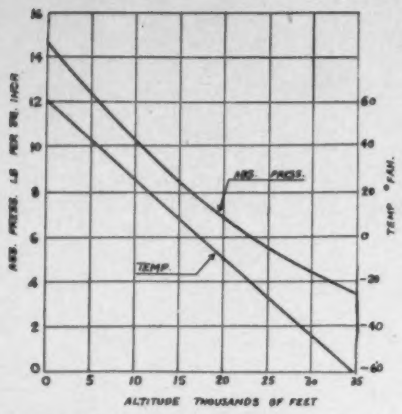


Fig. 15. Altitude chart for atmospheric air.

process control, and fuel or power costs. The selection of drive usually lies between steam turbine and electric motor and determined by the availability of steam supply or electrical power.

For large units more careful consideration is given to reliability and to the operating economics of both schemes, especially if the turbine is supplied for mixed-pressure or back-pressure operation or a combination of both. It must also be remembered that charges for electrical power taken from the Grid can vary in different districts.

High-pressure turbo-compressors of large capacity, *i.e.* from 20,000 cu.ft./min. upwards, are often compared in performance with reciprocating units because there is a substantial saving in power shown by the latter owing to its high efficiency. But if one takes into account comparative details of installation costs, maintenance, reliability, the problem of pipeline surges and necessity for air vessels, etc., there is little advantage, if any, shown by reciprocating units, particularly when compared with steam-turbine-driven compressors operating on back pressure.

Whilst diesel or gas engines can be used as drives, their application is limited because of their relatively low operating speeds, necessitating the use of two-stage speed-increasing gears and fluid couplings.

In general, the best form of prime mover for driving turbo-machinery is one that can be direct coupled and capable of stepless speed variation without undue sacrifice in efficiency, and it is obvious that steam turbines best fulfil these requirements.

Mechanical design

Turbo-blowers are provided with either a cast-iron or fabricated-steel casing with impellers of hot-forged sheet metal of riveted construction or cast steel or equal when open-type impellers are used. Stainless steel is also used for certain operating conditions.

High-pressure turbo-compressors are provided with cast-iron, semi-steel or steel casing horizontally split, depending on the final discharge pressure and temperature.

The impellers are either forged and milled or of the fabricated type, whilst the diffusers are made in cast iron or semi-steel and milled.

The main bearings are of the precision journal type with forced lubrication, and a double-acting Michell thrust bearing is provided in addition to the balance piston.

For safety in the operation of high-speed turbo-machinery it is essential that the critical speed of the unit together with impeller stresses should be kept within reasonable limits. Any textbook on the design of turbo-machinery will provide the information required.

Occasionally, with a turbo-compressor having a large number of stages, the first critical speed is passed through before the running speed is reached, otherwise the shaft diameter would be too large to give a good thermodynamic efficiency.

Performance

To give some indication of how various other gases behave when compared with air the diagram shown in Fig. 14 has been prepared for an uncooled multi-stage turbo-compressor with suction conditions of 14.7 p.s.i.abs. at 100°F. and based on an average pressure coefficient of 0.55, the polytropic efficiency being taken as 75%. These curves show the value of the compression ratio plotted against number of stages.

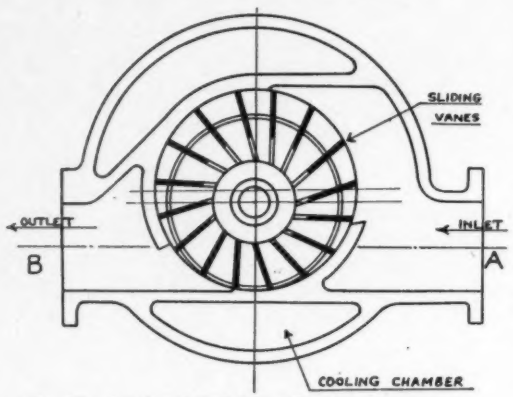


Fig. 16. Sectional end-view of rotary compressor.

Properties of gas mixtures. It is sometimes necessary to provide turbo-machinery for the compression of gas mixtures whose chemical composition is usually given. Before this can be done the thermodynamic properties of the gas must be considered. Avogadro's law states that equal volumes of gases having the same pressure and temperature contain an equal number of molecules. Dalton's law stipulates that each constituent of any gas mixture acts as if the other constituents were not present. This leads to the relation:

Specific gravity of any gas mixture

$$= \frac{m}{28.95}$$

where m = Molecular weight of the mixture.

28.95 = Molecular weight of air whose specific gravity is unity.

Chemical and physical properties of gas mixtures can be readily obtained from standard tables.

Effect of altitude. An increase in altitude causes a decrease in pressure and temperature of the atmosphere and is shown diagrammatically in Fig. 15. This diagram can be used to estimate the approximate performance of turbo-machinery when operating above sea-level.

Parallel operation. For satisfactory parallel operation of turbo-blowers or compressors they must work on the stable part of the characteristic, *i.e.* to the right of the surge point. Satisfactory parallel operation on the unstable part of the characteristic is not possible because one turbo-blower or -compressor will discharge against a somewhat lower resistance than the other owing to small differences in the arrangement of discharge mains which will result in different turbulence and friction losses.

A slight increase in the system demand will cause the blower or compressor with the lower discharge pressure to deliver more air or gas, thus causing the discharge pressure to rise on moving to the right on this part of the characteristic. The other blower or compressor, discharging at a lower pressure, will reduce its delivery and throw more load on the first unit. The result is that the blower or compressor with the higher resistance ceases to deliver, whilst the other unit endeavours to handle the whole of the system demand.

The rotary compressor

The rotary compressor has been in use for many years with an established reputation for mechanical reliability. Its design is simple and robust and provision for water cooling is conveniently arranged.

Fig. 16 shows an end view of a rotary compressor with its eccentric rotor, and from which the principle of operation can be easily seen. Air or gas enters at A and is discharged at B. The rotor bearings are

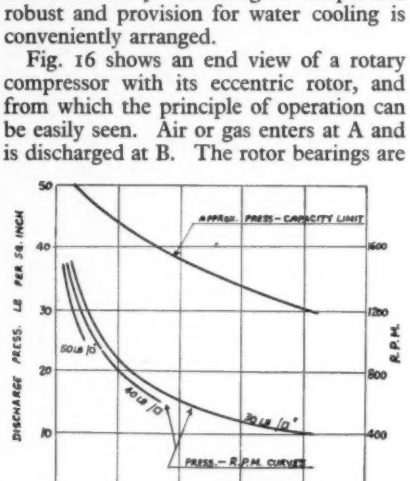

DISCHARGE PRESS. LB PER SQ. INCH
R.P.M.
APPROX. PRESS - CAPACITY LIMIT
50 LB /0"
40 LB /0"
30 LB /0"
PRESS. - R.P.M. CURVES
CAPACITY CUB. FT. OF FREE AIR PER MINUTE

Fig. 17. Typical performance curves for a single-stage rotary compressor.

usually of the roller or deep-groove ball-bearing type designed and proportioned to take care of the out-of-balance side thrust.

Rotary compressors have many advantages, some of which are: simplicity of design, adaptable for direct drive by electric motor, low installation cost, quiet operation, discharge free from pulsations and oil-free discharge.

For mechanical reasons, however, and particularly from the viewpoint of overall efficiency, there are commercial limits to the outputs and discharge pressures for this type of compressor, and Fig. 17 gives a general indication of their performance range. For higher pressures, two compressors in series can be used.

This type of rotary machine can be readily adapted for vacuum service and is then known as a vacuum pump.

New Iron Industry in South Africa

GERMAN PROCESS USES CHEAP COAL AND LOW-GRADE ORES

By W. Williams

THE iron and steel industry in South Africa has expanded rapidly in recent years, the State-sponsored I.S.C.O.R. being responsible for the bulk of production with works near Pretoria and at Vanderbijl Park. However, persistent steel shortages caused by the post-war boom in building and the rapid growth of secondary industries stimulated private enterprise into examining the possibility of augmenting the supply of iron by utilising the vast reserve of medium-grade ore which is available in certain areas of the North-East Transvaal.

In 1950 the Dominion Iron & Steel Corporation decided to go ahead with the erection of a plant at Airlie, and this factory is shortly expected to commence production of pig iron. The process to be used is new in South Africa, although many units are already working in different parts of the world. It is known as the Krupp-Renn process and it has been developed specifically to utilise medium- and low-grade iron ores which are unsuitable for normal blast furnace operation.

The plant is built at the site of vast deposits of iron ore, which are estimated to contain at least 120 million tons of ore in the surface layer alone with additional ore in deeper layers. The average analysis of the iron ore is about 47% with a high silica content of approximately 24%. The ore can be delivered to the factory at low cost, due to the fact that open-cast mining is possible. After preliminary crushing, the ore is delivered by overhead conveyor direct from the quarries to the plant. This eliminates the expensive railage charges which are incurred at other South African iron works.

Raw materials

Apart from iron ore, the process to be used requires adequate supplies of coal and limestone. Coal is readily available from the nearby Witbank coal mines and cheap duff coal is utilised in the Krupp-Renn process thereby eliminating the cost of treating high-grade coking coal as used in the normal blast furnace method of iron production. Limestone is also easily obtainable from the dolomite layers at Vlakplaats, which is only eight miles from the factory site. About 10% limestone is required for the fluxing of iron in the new process.

An interesting feature of the process is the manner in which high-silica ores can be used. Indeed, a minimum silica content of from 15 to 20% is essential for successful operation and this figure may be considerably exceeded, whereas the efficiency of a blast furnace is greatly reduced by the presence of even small amounts of silica.

The factors discussed indicate that production costs of iron at the new plant will be very low and it is anticipated that rapid expansion will be possible in view of the rising demand for steel not only in the Union but also in the neighbouring territories to the north. Initial production is estimated at 70,000 tons of iron annually. Converters, rolling mills and ancillary equipment will later be added and the bulk of the crude pig iron will be converted into some 48,000 tons of mild-steel products. The factory layout is planned so that additional kilns may be added without difficulty for increased output.

The Krupp-Renn process turns out crude iron in the form of 'loups' or nodules and these can be marketed direct or converted to steel of the desired analysis in a furnace of conventional design. Carbon, phosphorus and sulphur contents will be regulated by addition of anthracite, quicklime and manganese ore, respectively.

This new plant of the Dominion Iron & Steel Corporation has been planned and erected under the supervision of the German Krupp company. The giant rotary kiln, which is capable of producing nearly 6,000 tons of iron each month, is about 210 ft. long, 18 ft. in diameter and weighs over 600 tons. It was transported from Germany in sections, but even so, movement of the individual pieces from the coast to the Northern Transvaal presented some major problems due to the size and weight of the sections.

The Renn process was invented by Dr. F. Johannsen and developed by Krupp, being first used on an industrial scale in 1937. It is a development of the Waelz process by means of which zinc, lead and tin ores are treated in rotary kilns, giving metal oxides by volatilisation. In the Renn process, the iron is produced in the form of nodules, which are separated magnetically from the slag. Recovery is said to equal that of the blast furnace and be far better than that of the iron sponge process.

Kiln operation

The kiln is operated in the manner of a horizontal cement kiln, raw materials being charged to the upper end and working gradually down through the various zones. The iron ore and solid fuel are reduced to small size before charging to the kiln and to the mixture is added flue dust settled in the dust chamber and the so-called magnetic concentrate, an intermediate product of the process. The mixture passes first through the preheating zone of the kiln where it is dried and the temperature reaches about 600°C. In the middle zone, some 60% of the total kiln length, reduction of iron oxide to metallic sponge is effected at temperatures from 600 to 1,000°C. Hot gases, moving in counterflow, contain sufficient oxygen to permit continuous burning of carbon monoxide. The rotary kiln wall ensures a uniform transfer of heat through the reaction mass. The kiln temperature is regulated by a heating flame at the discharge end which is operated as required by burning coal dust or oil. Beyond the reduction zone is the lumping zone where nodulising takes place. By means of baffles the iron is kept at a greater depth in the last zone and so remains in it for several hours, whereas it has passed through the heating and reduction zones in some 30 to 50 min.

The nodules formed by the welding together of the iron sponge are mixed with a semi-liquid slag. The exit mixture is selectively crushed and then separated magnetically to give nodules low in slag.

The new plant here described represents a major and novel achievement in South African industrial development. By successfully utilising relatively low-grade ores and waste coal, it enormously increases the potential mineral wealth of the country, and several further plants of this type are planned to follow once the present unit is producing.

Copper-alloy globe valves (B.S. 2060: 1953, 4s. net). This is the first of a series of standards for copper-alloy valves for general purposes. Other series for ferrous valves for general engineering use will follow. This standard specifies requirements for rating, design and manufacture, materials, dimensions, tests and marking for copper-alloy globe, angle and oblique (or 'Y') valves with rising stem, inside or outside screw, with flanged or screwed ends, of Classes 100, 125, 150, 200 and 250 for a range of nominal sizes $\frac{1}{4}$ in. to 3 in.

Fuel Chemists' Research on the Fischer-Tropsch Process

THE FISCHER-TROPSCH process is generally regarded as the most promising method of producing liquid fuels and chemical products from coal and it is clearly desirable that up-to-date knowledge and first-hand experience of this process should be available in this country. The continued study of the process at the Fuel Research Station ensures the existence of a centre of such information for the benefit of the Government and of industry both in the United Kingdom and the Commonwealth overseas.

A description of the latest research on this important process at the Fuel Research Station is given in *Fuel Research*, 1953, published by the D.S.I.R. (2s. 6d. net).

In studying the process with laboratory-scale plant, particular attention has been paid to the effect of changes in the composition of the feed gas because water gas ($H_2/CO = 1$ to 1.2) or gases richer in carbon monoxide ($H_2/CO = 0.65$ to 0.75) are less expensive to produce from coal than the conventional synthesis gas with $H_2/CO = 2$. Investigation of the liquid-phase (slurry) process has been continued with laboratory-scale plant and a pilot-scale reactor has been constructed and erected. A successful run of 15 days' duration has been carried out with the pilot plant using the fluidised catalyst technique; an output of 50 to 60 gal./day of oil and other useful products was achieved. Further progress has also been made in the investigation of the reaction mechanism and of the properties of the iron catalysts used for the synthesis.

The fluidised catalyst process

Following minor modification to the 50-gal./day pilot plant, made in the light of the trial run reported last year, a more successful 15-day run has been carried out. A charge of 180 lb. of mill-scale catalyst (45% freshly prepared catalyst, 55% catalyst recovered from the trial run) was reduced for 24 hr. in pure hydrogen at a temperature of 430 to 445°C. and a pressure of 5 atm. Synthesis was started using gas with $H_2/CO = 2.5$, a pressure of 20 atm. and a temperature of 320°C. During the first four days the H_2/CO ratio of the gas was gradually reduced to 1.9 and the temperature was increased to between 325 and 330°C. After operation for seven days, the CO-conversion was 93% and the $(CO + H_2)$-conversion was 80 to 82%.

The pressure was then increased to 30 atm. and the recycle ratio was increased from 1.5:1 to 2.5:1 to maintain the requisite linear velocity in the reactor. The CO-conversion increased to between 96 and 97% and the $(CO + H_2)$-conversion to 92%. After five days' operation under these conditions (total running period 12 days), a leak of gas and vapours at the outlet of the reactor cooling system necessitated shutting down for 24 hr. When operation was resumed under the same conditions, the $(CO + H_2)$-conversion was only 89.1% compared with 92% immediately preceding the shut down. After 60 hours' operation, a blockage in the product outlet system caused another shut-down. After clearing the blockage, synthesis conditions were re-established and again a sharp fall in conversion was observed. After only six hours' steady running, a blockage developed at the same point as before and the run was terminated.

After the second day of the run it was observed that the dust filters at the top of the reactor had failed and catalyst fines appeared in the effluent product stream. The blockages which brought the run to an end were in the short line connecting the heat exchanger and condenser and consisted not, as was expected, of compacted catalyst dust, but of basic iron salts of fatty acids formed by the attack of the acid reaction water on the catalyst dust.

Apart from this failure of the filters, the plant with its ancillary equipment, controls and instruments worked well and, after the first four days of the run, the operation of the plant was left in the hands of trained industrial staff. No evidence was found of 'channelling' in the catalyst bed or of other departures from smooth fluidisation.

Carbon formation was satisfactorily low, being 0.018 lb./lb. catalyst/day. The depth of the fluidised bed, which was initially 4.8 ft., increased as the result of carbon formation to 6.7 ft. during the run. If the filters had prevented any escape of solids from the reactor, the depth of the bed would have increased to just over 7.5 ft., the position of the catalyst overflow line.

A series of runs has been carried out in the 1-in.-diam. unit, under conditions closely reproducing those employed in the pilot plant, using fresh mill-scale catalyst, catalyst withdrawn from the pilot plant after reduction but before synthesis, and catalyst discharged from the pilot plant at the conclusion of the run. These runs showed that the percentage conversion of reactants is appreciably higher in the small unit than in the pilot plant. Thus after nine days under the same synthesis conditions with the same sample of reduced catalyst the $(CO + H_2)$-conversion was 92.8% in the pilot plant and 97.3% in the small unit. Catalyst taken from the pilot plant at the conclusion of the run and transferred to the 1-in. unit (without any reactivation treatment) gave a conversion of 92.8% under the same operating conditions as those used during the last 6 hr. of the pilot-plant run when the conversion was only 83.7%. This difference is believed to be due to the smaller height/diameter ratio of the fluid-bed in the pilot plant compared with that in the small unit. Recent studies of flow patterns in fluidised beds have shown that, as a result of a departure from 'piston flow' in such systems and of the tendency for gas bubbles to pass rapidly through the bed, the extent of conversion of gaseous reactants will decrease markedly as the height/diameter ratio of the bed is reduced.

The unexpectedly low average molecular weight of the products and the high proportion of compounds containing oxygen produced in the pilot plant were shown by the small-scale tests to be characteristic of the mixed catalyst employed and not of other conditions of operation of the pilot plant.

The necessary additional equipment has been installed to permit operation of the pilot plant with a mixture of steam and gas deficient in hydrogen (water gas or producer gas) as the feed.

The liquid-phase ('slurry') process

In experiments with the precipitated iron: copper: alkali catalyst, efforts have been directed towards devising a method of pretreatment to prevent the rapid collapse in activity at temperatures above 260°C. experienced when this type of catalyst is reduced in pure hydrogen. The most successful treatment so far discovered consists in passing water-gas through the catalyst at atmospheric pressure while raising the temperature rapidly to 320°C., and then allowing the catalyst to cool to 200°C. before starting synthesis with water-gas at 10 atm. This treatment, which takes a total time of 3 to 4 hr., effects a 75% reduction of the iron compounds to metal without any appreciable formation of iron carbide. A catalyst so treated showed no decrease in activity during 15 days' operation with water-gas at 10 atm. and 285 to 290°C. The conversions and yields of products obtained under these conditions represented no significant improvement over those obtainable with mill-scale catalysts. The latter type of catalyst would be much cheaper to manufacture than the precipitated type and is easier to separate from the slurry by filtration during adjustment of the slurry level in the reactor.

Although the search for improved catalysts of other types is continuing, further work has been carried out with mill-scale catalysts to study their performance with gases richer in carbon monoxide than the synthesis gas ($H_2/CO = 2$) formerly used

with them. The results show that the gas conversion, and hence the total yield of products, decreased with reduction of the H_2/CO ratio of the feed gas and suggest that, in slurry operation, in contrast to operation with fixed-bed reactors, the presence of inert diluents in the gas is not completely compensated for by increased operating pressure. The results indicate the beneficial effect of reduction in the H_2/CO ratio of the feed gas on selectivity, *i.e.* on the ratio of higher hydrocarbons to methane in the product.

In experiments in the 2-in.-diam. slurry reactor using slurry depths of 9 to 12 ft. it has been found that partial sedimentation of the mill-scale catalyst, accompanied by a fall in gas conversion, tends to occur during the first three or four days. Provided that a linear gas velocity of not less than 0.05 ft./sec. was maintained under working conditions and the catalyst concentration did not exceed 500 g./litre of slurry, no such sedimentation had been experienced in slurries up to 30 in. in depth. It now seems probable that for large-scale operation the mill-scale catalyst could only be employed in conjunction with a suitable agent for stabilising the dispersion. In all their work on the slurry process using fused-iron catalysts, the U.S. Bureau of Mines found it necessary to add a small quantity of 'Bentone 34,' an organophyllic clay, to the slurry as a suspension aid.

A pilot-scale slurry reactor 23 ft. long and 10 in. in diameter, fitted with internal cooling tubes, has been constructed and erected alongside the fluidised-bed reactor.

Properties of catalysts

Mill-scale catalysts. Surface area and pore structure investigations with mill-scale catalysts have shown that extraction with water increases the area of the unreduced catalyst from 0.078 to 0.734 sq.m./g. but does not affect the surface area of the reduced catalyst, which is 1.5 sq.m./g. when reduction is effected at 450°C. Lowering the reduction temperature from 450 to 300°C. increases the surface area from 1.5 to 6 sq.m./g. Evidence was obtained that the pore diameters for all the catalysts examined were in the range 20 to 200Å and that pores with diameters between 20 and 60Å contributed 75% of the total surface. The total pore volume appeared to vary approximately directly with the surface area.

With a view to throwing light on the possible state of combination of the alkali in mill-scale catalysts and on the changes which occur on extraction of the catalyst with water, the formation and properties of a potassium ferrite have been examined. An intimate mixture of powdered mill scale and potassium carbonate in equimolecular proportions was heated at 1,000°C. for 2 hr. (conditions used in the preparation of the alkali-impregnated mill-scale catalyst). From the evolution of carbon dioxide and the loss of weight which occurred, a substantially complete conversion to the ferrite, Fe_2O_3, K_2O, appeared to have taken place. The *x*-ray diffraction pattern of the product agreed with published data for this compound and no other iron phase could be detected. On extraction of the ferrite with water, potassium hydroxide was liberated and *x*-ray examination of the extracted product showed complete absence of the double-oxide phase (Fe_2O_3, K_2O); a nearly amorphous phase was, however, observed which appeared to contain the haematite structure in a rudimentary form. Treatment of this material at 450°C. converted it gradually into finely crystalline haematite.

It seems possible that the enhanced activity of mill-scale catalysts which have been extracted with water is associated with a surface layer of finely divided iron derived from the decomposition of a ferrite.

Adsorption on composite surfaces. As the first stage of an attempt to apply adsorption methods to obtain information about the nature of complicated composite surfaces such as those of the catalysts used for synthesis, adsorption studies have been carried out on simple two-component surfaces prepared in such a way that their composition is known. Preliminary work was done with a kieselguhr-methanol surface, but this has now been replaced by dichlorodifluoromethane (CF_2Cl_2) adsorbed on anatase (titanium dioxide). This has the advantages that the anatase is crystalline and non-porous, and the CF_2Cl_2 is a more symmetrical molecule than methanol and should be immobile on the anatase surface at −195°C. The only uncertainty is that the packing of the CF_2Cl_2 molecules on the surface may vary a little with the number present.

Reaction mechanism

Studies based on the composition of the products. The observation, reported previously, that *n*-primary alcohols decomposed in the presence of hydrogen at 20 atm. to form hydrocarbons at a greater rate in the presence of a mill-scale catalyst which has been in use for synthesis than in the presence of a freshly reduced catalyst, has been confirmed by experiments at a lower temperature, 240 instead of 300°C. If this observation has any bearing on the behaviour of alcohols during the synthesis process, the alcohol content of the product obtained during the first few hours of synthesis on a freshly reduced catalyst should be greater than that of the products produced later in the life of the catalyst. In a synthesis experiment with freshly reduced mill-scale catalyst at 240°C. and 20 atm., it was found that the alcohol content of the liquid product distilling over the range 80 to 250°C. obtained during the first 6 hr. of synthesis was nearly twice the constant value attained after 24 hours' synthesis. It appears probable, therefore, that a proportion at least of the hydrocarbons in the products obtained by synthesis with iron catalysts has been derived from alcohols formed initially.

It has been considered that the relative proportions of the various hydrocarbon isomers with a given number of carbon atoms are independent of the synthesis conditions, that in fact, for a particular catalyst, the isomer distribution is controlled by a fixed ratio of probabilities of addition of a carbon atom to the end or to the end-but-one carbon atom of the growing hydrocarbon chain. To obtain further evidence on this point the distribution of the isomers in the C_6 hydrocarbons in four different synthesis products is being determined by infra-red spectrometry. Two of the selected products were prepared with a cobalt catalyst at 10 atm., the first under 'normal' conditions (temperature 190°C., (CO + H_2)-conversion 65%), and the second under conditions giving a product abnormally rich in alcohols (temperature 170°C., (CO + H_2)-conversion 15%). The remaining two products were obtained by synthesis with an iron (mill-scale) catalyst at 230°C. and 30 atm. in a fixed-bed reactor, and at 320°C. and 20 atm. in a fluidised-bed reactor. A broad fraction, to contain all the C_6 hydrocarbons, was separated from each product, treated to remove alcohols, acids, esters and other products containing oxygen, and hydrogenated in the vapour phase to convert the olefines into paraffins. The 'refined' products were then separated, using a spinning-band fractionating column with an efficiency equivalent to 40 theoretical plates, into 12 fractions covering the boiling range 36 to 83°C., suitable for infra-red analysis.

Studies based on radioactive tracers. In the synthesis with cobalt catalysts at atmospheric pressure, it had been found that, when more than 35% of diluent is added to the synthesis gas, the proportion of the total product which is liquid and solid is greater when the diluent is carbon dioxide or methane than when nitrogen is used. It seemed possible, therefore, that some of the methane and carbon dioxide might have been converted to higher hydrocarbons. The results indicated that any such reaction occurs to the greater extent with carbon dioxide, and the possibility could readily be tested by carrying out synthesis with gas containing carbon dioxide labelled with carbon-14. The radioactivity of the products obtained in an experiment at 185°C., using a synthesis gas ($H_2/CO = 2$) containing 50% of carbon dioxide, was negligible, and it was calculated that less than 0.5% of the carbon dioxide had been converted to hydrocarbons. It is considered, therefore, that the effect originally observed was not due to the conversion of the diluents into higher hydrocarbons.

A study is in progress of the hydrocondensation reaction between ethylene, hydrogen, and carbon monoxide. The product obtained by passing a mixture of these gases over a cobalt catalyst is similar

to Fischer-Tropsch synthesis product and preliminary experiments have been carried out with a gas mixture containing 5% of carbon monoxide labelled with carbon-14 and equal proportions of ethylene and hydrogen. Hydrocarbons of each carbon number in the range C_2 to C_{10} have been separated from a few grammes of product, the gaseous hydrocarbons C_2 to C_5, by displacement chromatography with a charcoal column, and the liquid hydrocarbons by fractional distillation. The specific activity (activity per carbon atom) of the hydrocarbon fractions has been found to rise with the length of the carbon chain, and a more detailed examination of the distribution of carbon-14 in the molecules is clearly necessary in order to elucidate the part played by carbon monoxide in the process of chain growth.

Nitrogen from Sewage Effluent

POSSIBLE NEW SOURCE OF FERTILISERS FOR BRITAIN

OPINION on the value the wastes from towns could have in agriculture has varied from the most optimistic to the completely sceptical. Now for the first time full details of what wastes are available and how they might be used have been made public in a report by the Natural Resources (Technical) Committee.* The Committee's main conclusion is that the potentialities of town's wastes are often overestimated and that composting is generally an uneconomic process. But they think that attention should be given to the problem of recovering the nitrogen which is lost in the effluent from sewage works. They point out that an estimate of the cost of nitrogen recovery from sewage compared with that of producing nitrogenous fertilisers by conventional methods would be useful.

The Committee's observations on these points may be summarised as follows:

Total nutrients available

About a million tons of dry solids are contained in the domestic and industrial sewage of England and Wales in any one year. Nearly 800,000 tons of this is recovered at sewage disposal works as sewage sludge; 350,000 tons of sludge are already applied to the land and a small proportion which contains toxic matter is not suitable for agriculture. The remaining 400,000 tons, which might be used, contains 10,000 tons nitrogen, 5,000 tons phosphoric acid (as P_2O_5) and 1,200 tons potash (as K_2O). A large part of the nitrogen in sewage, 60,000 tons a year, remains in the effluent and is discharged into rivers and the sea. Fine dust in household refuse contains about 20,000 tons each of nitrogen, phosphoric acid and potash. The putrescible matter, collected with the dust, contains about 4,000 tons of nitrogen.

All this nitrogen adds up to about half as much as is applied in fertilisers every year, but the unused sewage sludge is the only material immediately available for agriculture. Its nitrogen content is equivalent to only about 5% of the nitrogenous fertilisers bought annually by farmers.

Composting the putrescible matter in household refuse with crude sewage sludge has often been suggested, but only one-quarter of the unused sewage sludge could be used with the whole of the putrescible matter. The quantity of mature compost which could be produced is about 700,000 tons, containing 4,500 tons of nitrogen.

The Use of Towns' Wastes in Agriculture, H.M.S.O., 1s. 3d.

Economics of nitrogen recovery

The economical recovery of a substantial part of the nitrogen at present lost in the effluent of sewage treatment works could be a useful addition to our indigenous resources of fertilisers. An increase in fertiliser consumption, particularly of nitrogen, will be necessary if, through an expansion of agriculture, a marked increase in the output of home-produced food is to be achieved. While existing nitrogen fertiliser plant, through increases in efficiency, can further improve the annual output of fertiliser, new capacity will ultimately be required. The capital cost of a synthetic nitrogen plant has been estimated at as high as £200 per ton/year of nitrogen fixed, and that plant, having a capacity to give an output of 100,000 tons nitrogen a year, requires 100,000 tons of steel in its construction and an annual energy consumption equivalent to that of about 500,000 tons of coal. Provision for additional synthetic nitrogen fertiliser supplies, through the erection of new plant, would thus make large demands on the national resources.

Sewage treatment plants also represent a considerable capital investment by the community. In achieving the purification of sewage at a reasonable cost it has been proved necessary to aim at processes giving low production of sludge in order to keep down the costs of sludge disposal. While this aim must continue, any attempt to increase the utility of treatment plants, by the modification of old processes or the adoption of new, so as to increase the recovery of nitrogen should be encouraged. Information on the cost of nitrogen recovery from sewage is not available and no estimate appears to have been made of the probable cost of increased recovery. Such estimates would be of value in enabling a comparison to be made with the cost of producing nitrogenous fertiliser by the fixation of atmospheric nitrogen.

Methods of nitrogen recovery

Recovery of nitrogen from sewage effluent by ion exchange methods is technically feasible, but it is doubtful whether it would be economic on any large scale. A process of sewage treatment based on this principle has been in operation at two works in the United States. The process consists in removing the suspended solids by precipitation with ion compounds and lime, and the removal, from the settled sewage, of the basic nitrogen compounds by an ion-exchange reaction with zeolite. The zeolite is regenerated by washing with a relatively small volume of a solution of common salt and in this operation the nitrogen compounds, chiefly ammonia, are transferred to the wash liquid from which the ammonia is subsequently recovered. It is stated that the purification achieved compares favourably with that of the activated sludge process. The capital cost of the plant is less than for the activated sludge process, but the running costs are probably greater. Information on the percentage recovery of nitrogen or its cost is not, however, available.

Biological methods of fixation appear to offer a promising line of development, because part of the soluble nitrogen in the effluent is incorporated in the structure of the multiplying bacteria and may be recovered in the sludge by normal sewage practice. At Chicago, Houston, and Milwaukee in the U.S.A. the sewage is activated biologically, and the sludge, when separated and dried, is a high-grade nitrogenous fertiliser containing 6% nitrogen, which finds a ready sale as a fertiliser. A sludge of similar composition is produced at the new sewage treatment plant of the Colne Valley Sewerage Board and, although at present, after drying, it is used mainly as a fuel at the works, arrangements are in hand to put it on the market as a fertiliser base. At the Mogden works of the West Middlesex Main Drainage Board, the mixture of crude and surplus activated sludge is digested and after air-drying the bulk of it is disposed of as a manure. A small proportion of the semi-dry sludge is further heat-dried and pulverised to give a granular powder containing about 3% nitrogen; this is bagged and sold as a high-grade manure. A recent Dutch estimate states that about 70% of the nitrogen can be recovered in solid form from sewage by the activated sludge process; at present about 25% is recovered where the process is used.

Pallets. In a 9-p. pamphlet Weldall & Assembly Ltd. describe their many types of pallets available to industry. Apart from the familiar flat pallet for carrying and stacking any type of crated goods, there are post pallets with pressed feet for ease and safety in stacking for storage. These are recommended for soft cartons which must not be crushed in packing. Box pallets with either wire-mesh panels for readily viewing loose components, or solid sides, are illustrated. Storage racking is supplied and erected for use with the pallets.

Plant and Equipment

Ultrasonic cleaning of engineering parts

An ultrasonic cleaning plant, the first of its kind to be made in Europe and believed to be the first completely automatic unit in the world, has been made to the order of a well-known firm who require to clean small precision engineering parts to a degree not obtainable with conventional cleaning machinery.

It has been established that, if an article to which foreign particles, *e.g.* grease or other matter, is adhering is irradiated ultrasonically in a bath containing a suitable fluid, the part will be made chemically clean. The ultrasonic energy is able to reach those parts of the articles which are normally inaccessible, and foreign particles are rapidly dislodged. A suitable frequency and intensity are necessary depending on the nature of the material to be cleaned. In this particular plant the frequency is 1 megacycle and the maximum intensity at the transducers approximately 5 w./sq.cm. This means that the generator, which has an output capacity of 2½ kw., is sending out electrical pulses at the rate of 1 million/sec. The transducers, which are in this case barium titanate, vibrate in sympathy with the frequency of the generator and the energy is transferred from the transducers directly into the liquid.

Barium titanate is a man-made ceramic crystal which has the advantage over quartz of needing only low voltages for excitation and can, therefore, be operated in direct contact with the liquid.

The parts to be cleaned are placed in open wire-mesh trays. These run into the plant on rollers and are automatically backed up on a conveyor which takes them through the two-stage cleaning process. The cleaning fluid is recirculated through a magnetic filter in the first stage, and a combination of magnetic and ceramic filters in the second stage.

At the end of the conveyor system the trays are transferred to another roller conveyor on which they travel to the next stage in production. It is estimated that over one million parts will be cleaned daily in this machine. The variable-speed drive on the conveyor allows considerable latitude so that the plant can be run at a speed to match the production rate of the preceding processes.

The cleaning fluid in the tanks can be removed simply by the operation of valves, and a new charge introduced. The fluid, which will become charged with oil in the course of time, will be delivered by the pumps on the plant to distillation equipment so that it can be used again.

The plant is produced jointly by Ultrasonics Ltd. and Mullard Ltd. The company who ordered the plant wished to import a machine from the U.S.A., but they were referred to these two companies to see if a unit could be produced in this country. As no information was available as to the type of plant produced in the U.S., a unit had to be designed and produced from scratch in two months, owing to the urgency of the users' requirements.

Plant for ultrasonic cleaning of engineering parts.

High-pressure gas pump

In the years 1924-25 the German firms, Gutehoffnungshütte Sterkrade and I. G. Farbenindustrie Ludwigshafen adopted for the first time the idea of substituting rotary-type circulators for the reciprocating compressors so far exclusively used in the cycle of the high-pressure ammonia synthesis. The ever-increasing requirements of the chemical industry had given rise to this trend.

After many years of experimental work the so-called Maulwurf pump was developed. Its particular constructional feature is the pressure-proof housing which accommodates both the circulator and the driving motor at the full gas pressure obtaining. In the special chemical process the circulator draws in the circulating gas at a pressure varying between 2,844 and 4,266 p.s.i. and increases the pressure by 213 to 227 p.s.i., depending upon the requirements and the number of stages in use.

Advantages claimed are that the gas flows evenly in a closed high-pressure circuit without a marked change of direction; the gas does not come into contact with oil, a feature which increases the life of the catalyst; and no high-pressure glands are in contact with moving parts.

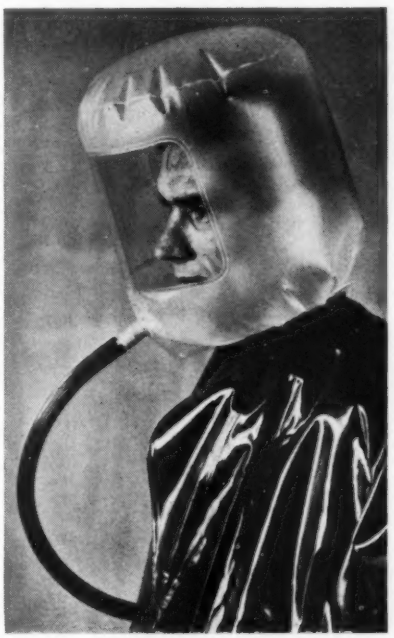
The circulator is of the multi-stage design and construction. The standard types have 14 stages, one to four of which may be omitted and replaced by dummy stages if the maximum pressure rise obtainable is not required. The standard types for volumes between 118 and 235 cu.ft./min. at inlet have the same outside dimensions.

The pressure-volume characteristics of the circulator are curved only slightly, so that, it is claimed, it is possible for the pump to operate far below and above the optimum point for which it has been rated. The circulator can, therefore, be adjusted to the various operating conditions within wide limits.

The correct number of stages is installed to give the desired throughput, and the circulator as such automatically adjusts itself to the required pressure rise, depending upon the resistance of the circuit. The axial thrust of the rotor of the circulator is balanced automatically, no special thrust bearing being required, and this feature also centralises the rotor of the motor through the coupling.

The motor itself is a special design of Siemens-Schuckertwerke's Dynamowerk, Berlin. Its normal output is 375 kw. with a speed of 3,000 r.p.m. and a frequency of 50 cycles. The same type of motor will be used for smaller outputs.

Agents for these pumps in the United Kingdom are Dollery & Palmer Ltd.



Inflatable plastic hood.

Inflatable hood

An inflatable plastic hood has been developed by Plysu Products Ltd. to protect the wearer from dust particles and vapours in chemical plants and other situations where similar harmful conditions exist.

The hood, which is fabricated from PVC sheet with high-frequency welded seams, has a transparent visor and a generous skirt which tucks into the neck of normal protective clothing and covers the shoulders. A compressed-air line is fitted to the hood and the constant flow of

air keeps the wearer reasonably cool, prevents the formation of moisture or misting effects on the visor and also prevents the entry of dust or vapours at the skirt. Even if a material defect should develop in the hood, the entry of dust or vapour is still prevented, as the internal pressure is slightly higher than the external atmosphere.

A complete plastic suit, with an integral transparent hood, has been developed which also incorporates the compressed-air principle. It is designed for use in atomic energy plants to provide complete protection against radioactive dust and particles. The first of these suits have just been supplied to Harwell and the Windscale plutonium factory in Cumberland. Compressed air is fed into the suit to maintain an internal pressure of approximately ½ p.s.i., the excess escaping through an exhaust valve in the back of the jacket.

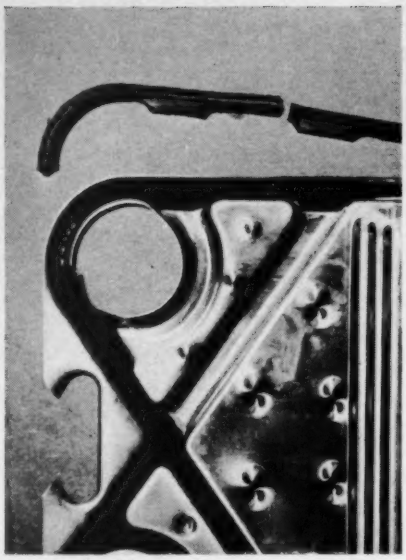
'Polarising' heat exchanger gaskets

One of the more important advances that have been made in recent years in the study of adhesion is the recognition that the polarity of two surfaces which are to be joined together must be compatible, in that good adhesion between the two polar surfaces is much more likely to take place than between a polar and a non-polar surface. It follows that, in order to cause rubber—a non-polar material—to adhere to a polarisable surface such as that of stainless steel, the surface of the rubber must be made polar.

The A.P.V. Co. Ltd. has been carrying out a great deal of research work into the application of this principle to improve the adhesion of the rubber gaskets on the stainless-steel plates of *Paraflow* heat exchangers. Now a method has been developed of subjecting the gasket to a rapid chemical treatment which changes the nature of the surface to be mated with the stainless-steel heat-exchanger plate groove. The surface of the polarised rubber is virtually unchanged in appearance to the naked eye, but under magnification is seen to be covered by finely spaced parallel cracks.

In the accompanying photograph the high strength of the bond is apparent from the fact that during attempted removal of the gasket at normal temperature the rubber has torn through at some areas. It also shows the good adhesion which has been obtained at the edge of the rubber 'tabs.'

It is, however, quite a simple matter to remove the gasket from a plate. This is done by softening the adhesive by means of a small flame, such as a painter's blowlamp, carefully applied to the back of the rubber groove. At about 300°F. the adhesive is sufficiently thermoplastic to permit the gasket to be gently lifted away from the plate without any tearing, and in this way it is possible to remove a gasket completely in less than 2 min. The



Polarised rubber gasket on heat exchanger plate. High strength of bond demonstrated by the fact that during attempted removal of the gasket at normal temperature the rubber has been torn through.

Surface of polarised rubber showing the finely spaced parallel cracks.

adhesive generally remains on the gasket, so that the plate groove requires very little cleaning prior to the insertion of a new gasket.

The replacement 'polarised' gasket is supplied already coated with cement and may be inserted into a plate groove previously treated with a coat of A.P.V. cement, without further preparation. The subsequent treatment is that normally recommended when re-rubbering A.P.V. plates.

New welding technique for stainless steel tube

When a production welding job is of sufficient volume to justify use of fully automatic equipment, two basic requirements have to be met to achieve the best results. Parts have to fit closely and they have to be held in proper relationship by substantial jibs and fixtures. At the Damascus Tube Co., Greenville, Pennsylvania, where thousands of feet of corrosion-resistant pressure tubing in light-gauge stainless steel are produced for a wide variety of uses, both these requirements are met by the use of inert-gas-shielded tungsten arc welding and automatic equipment.

In the forming process, flat cold-rolled stainless strip is fed continuously from coils through a series of contoured rolls which gradually shape the steel into a tube. Butted edges are welded together without filler metal to make a continuous wall. The inert-gas-shielded tungsten arc process produces a homogeneous weld possessing substantially the same physical and corrosion-resistant properties as the parent metal.

The method of welding employed by the Damascus Tube Co. is described in a recent issue of *Steel*. It is pointed out that carbide precipitation is an important problem when welding stainless steel. If the metal is kept at elevated temperatures for any length of time, it loses its corrosion-resistant properties because the carbon combines with the chromium. Precipitation is minimised in the inert-gas process because high welding speeds reduce the area exposed to high temperatures. The temperature is governed by current used, which in turn is controlled by metal thickness. However, by using helium and direct-current straight polarity, high currents may be used and very high welding speeds employed. Thus, while the current is high, the speed is such that only a narrow zone is exposed to temperatures which are conducive to carbide formation.

Fast cooling. With only a narrow zone heated, the cooling rate is rapid. Best results are obtained by the use of small electrodes (non-consumable) and fast travel speeds. Damascus Tube Co. is using ⅛-in.-diam. thoriated tungsten with 25-cu.ft./hr. helium and 223 amp. With this the company is getting a welding speed of 16 in./min. minimum on 1½-in.-diam. No. 304 stainless tubing, having 0.120-in. wall thickness. Speeds of 96 in./min. are obtainable on thinner sections.

Greater speed. Speed of welding is a function of the rate of heat input to the work and varies with the mass of metal being welded. Use of helium in this instance, which provides a hotter arc than that obtained with argon, contributes to welding speed. Flux-free welding with no slag and spatter to clean up means additional time and labour savings. After welding, the tubing is annealed and then fed through the swager, carefully blending the weld to the outside and inside diameter contour. Operations which follow involve annealing for specified ductility, straightening, pickling and final inspection when each length is tested hydrostatically and mechanically for gauge, size, tolerance, straightness and surface condition, both inside and outside.

New Books

New British Chemical Engineering Textbook

THIS is the first volume of a comprehensive text on chemical engineering to serve both students and practising engineers in industry.* It is also the first work on this scale which is native to this country, but since we share the common concepts and units of the subject with the U.S.A. this fact is significant principally as evidence that Britain is at last appreciating the importance of chemical engineering. A secondary but noteworthy result of publication in this country is the reasonable price—roughly half that of standard American texts on the subject.

The book begins with a brief but lucid chapter on units and dimensions. The main subject matter is then dealt with under the three headings of fluid flow, heat transfer and mass transfer. The final section is devoted to a detailed study of humidification and water cooling, which provides an admirable illustration of the application of principles elucidated in the earlier chapters.

The pattern of each section is the same and comprises a theoretical treatment of the topic, which is then given point by the discussion of practical applications and equipment design with worked examples. It is a pity that no problems for the student are provided. These are particularly important in a book of this nature, since understanding of the text is proved and facility in the subject improved by the working of such problems.

Throughout the book emphasis is given to the fundamental nature of the techniques and operations with which the chemical engineer is concerned. The fluid flow section begins with a study of energy relationships from the standpoint of thermodynamics which forms a good introduction for the very detailed study of flow conditions in pipes and channels which follows. The chapter on flow measurement discusses all the usual types of equipment, but seems a little inconsistent in giving what may be termed practical hints which are yet too brief to be of real value.

Pumps for chemical works are dealt with comprehensively, but there is a tendency for the pattern of this chapter to reflect the relative amount of literature on each type, those particularly amenable to mathematical analysis, such as centrifugal pumps and reciprocating compressors having the lion's share.

The section on heat transfer begins with a conventional treatment of conduction, convection and radiation. Particularly useful is the discussion of non-steady-state conduction and the inclusion of information on heat transfer in reaction vessels with jackets and coils. Shell and tube exchangers are described and well illustrated, although one could wish that both in this section and that on pumps more space had been given to the excellent line drawings and less to photographs familiar to all who look at the advertisement pages of technical journals.

Next follows the section on mass transfer which, after a brief discussion of diffusion in gases and liquids, devotes a considerable space to the relationship between momentum, heat and mass transfer and to a consideration of the boundary layer state. The latter is treated very fully and will be useful not only to students but to all chemical engineers who wish to become well versed in an aspect of their work which is of rapidly growing importance.

The last section, which deals with humidification and water cooling and particularly the design of equipment for the same, adequate though it is, seems somewhat of an anticlimax after the rather rarefied atmosphere of the previous chapter. Perhaps it would have been more logical to include it in the next volume, which we are told will deal with the 'Physical principles involved in the design of chemical plant.' Possibly consideration of space prevented this. However, the chapter serves as an admirable foil to what has gone before and reminds the reader that chemical engineering problems are finally practical ones.

At the end of each section there are good literature references well up to date and very complete lists of nomenclature.

Large folding charts are included giving pipe friction factors and air-water humidity relationships. The index—a favourite 'bookshop test' of technical books—seems rather short for such a volume, but this is presumably because of the proportion of space devoted to mathematics, since a number of spot checks shows it to be quite adequate. The printing and presentation is attractive and the volume well produced. In fact, judging by the difficulty of finding them, misprints are remarkably few for such a book.

It is easy with a book of this size and scope to seize on a few particular points presented in a manner which is unfamiliar and hence disagreeable at first sight, but this is no test for such a volume. It is very difficult if not impossible fairly to pronounce upon a text of this nature in a review, since the real test of its value will be its use by generations of students and their lecturers.

What can be said with confidence is that every serious student and practitioner of chemical engineering will want to read and use this book. It is essentially a book for the desk rather than the bookshelf and a valuable and well-written guide for people at almost every stage of the profession.

D. C. FRESHWATER

Chemical Engineering, Vol. I, by J. M. Coulson and J. F. Richardson. Pp. viii + 370 (3 charts). Pergamon Press, London. 38s. 6d. net.

Contributions and Correspondence

THE EDITOR *welcomes practical articles and notes on chemical engineering and industrial chemical subjects with a view to publication. All contributions, which should be fully illustrated whenever possible, are carefully considered. A preliminary letter or synopsis is advisable. Address such material to* THE EDITOR, CHEMICAL & PROCESS ENGINEERING, Stratford House, 9 Eden Street, London, N.W.1.

Letters for publication on any of the subjects covered by this Journal are also invited.

Liquid-Liquid Extraction

This* is a declassified version of an earlier report written in November 1950. The opportunity has been taken of including some of the more important papers published since then.

The literature dealing with the theory of mass transfer between two liquid phases is critically examined. The analogous cases of mass transfer in solid-liquid and in gas-liquid systems, and of heat transfer, are also considered.

It is shown that the Whitman two-film concept, which is frequently used as the basis of approximate correlations of experimental data, is only strictly correct when transport to the interface is by molecular diffusion and any chemical reaction faster than this. Under conditions of high turbulence, transport to the interface may be by eddy diffusion, the transfer rates being then independent of the molecular diffusion coefficients. Since eddy transfer is much more rapid than molecular diffusion there is more likelihood of a chemical step being rate-determining under these conditions. The same system may thus be diffusion controlled at low degrees of turbulence and chemically controlled at high degrees of turbulence.

The properties of liquid-liquid interfaces are briefly reviewed, attention being drawn to the difference between the interfacial and bulk phase properties of the solvents and solutes.

Liquid-Liquid Extraction, by J. B. Lewis. An A.E.R.E. Report. Ministry of Supply, London. Pp. 22. 3s. 6d. net.

World News

GREAT BRITAIN

Gas-from-oil schemes criticised by Prof. Newitt

The gas industry's plans for making gas from oil have been vigorously criticised by Prof. D. M. Newitt, Professor of Chemical Engineering at Imperial College, and a former President of the Institution of Chemical Engineers. He said that the industry had long recognised that new methods of gas making would have to be developed to deal with the wide range of non-caking coals and that processes of total gasification would eventually be required. Twenty years of research had been devoted to finding the solution to the technical and scientific problems involved, and while the results had been most encouraging there had been a great lack of initiative in exploiting them. Today there was not a single large-scale total gasification unit either projected or in operation.

Prof. Newitt makes these points in a letter to *The Times* in which he states that the alternative—the production of gas from oil—has little to be said in its favour other than that it relieves the industry from the financial risks and the hard work associated with introducing a new process. It was also something of an anomaly that while plans for manufacturing gas from oil were receiving official encouragement the large oil refineries were at the present time burning to waste quantities of high-grade tail gases equivalent to nearly 25,000 tons of coal a year.

Total gasification processes at the pit-head could achieve great economies in the gas industry and make invaluable contributions towards smoke abatement and public health. 'But vigorous and imaginative planning is required and no time and money should be wasted on the retrograde step of making the industry dependent on a costly imported raw material.'

Titanium plant

What is believed to be the first plant for the melting of titanium and titanium alloys in Sheffield and which will represent a major contribution to titanium production capacity in Great Britain is to be installed by William Jessop & Sons Ltd. Technical aid has been obtained under an agreement with one of the biggest American producers of titanium and Jessops are to instal melting furnaces for titanium metal and titanium alloys on a site still to be determined. They will also be installing, in due course, special manipulative plant for forming these metals into vital aircraft parts.

Sulphuric acid production

The summary of monthly returns from acid makers issued by the National Sulphuric Acid Association Ltd. for the period April 1 to June 30, 1954, and excluding all Government plants, shows a production of 512,206 tons of 100% H_2SO_4—160,817 tons by the chamber and tower process and 351,389 tons by the contact process.

American equipment to be made in Britain

Blaw Knox Ltd. of London, S.W.3, have concluded an agreement with the Blaw-Knox Co. of U.S.A. for the manufacture in Britain of *Buflovak* equipment for evaporating, drying, solvent recovery and other processes.

In equipment now to be built in Britain the latest refinements of design will be incorporated. Plant will now be available to British industry and for export against payment in Sterling.

This new section of Blaw Knox Ltd. business will be controlled by its Chemical Plants Department from the company's head office at 90-94 Brompton Road., London, S.W. 3, under the management of Mr. Guy N. Harcourt, who was vice-president (Engineering) of the Buflovak Equipment Division of Blaw-Knox Co. of America (see 'Personal Paragraphs').

Bowater's paper and pulp expansion

All the plants of the Bowater Paper Corporation Ltd. in the U.K. and overseas continue to operate to capacity and the company is experiencing some difficulty in fulfilling all its obligations to its customers, particularly in the fields of newsprint and magazine paper, but they are doing their utmost to press forward with developments in hand designed further to increase productive capacity.

This was stated by Bowater's chairman, Sir Eric Vansittart Bowater, at an extraordinary general meeting of the company, before he went on to announce the starting up of the new Tennessee mills, discussed on another page in this issue. He said that the additional output of newsprint and pulp provided by the Tennessee mills constitutes a valuable contribution to the requirements of Southern United States newspaper publishers and to the company's own requirements of this type of pulp; moreover, it is another step in the company's policy of controlling some part of their requirements of the many varieties of raw materials that they consume.

The chairman recalled that some 30 years ago, the capital of the then private parent company was £125,000 and it had just decided upon the construction of its first manufacturing plant, now Bowater's Thames paper mills. Today the company's assets exceed £75 million and the productive capacity of its plants throughout the world is of the order of 1 million tons of paper annually, and each year it draws from its own resources some 800,000 tons of raw materials.

Hackbridge and Hewittic's new extension

To meet the demands for higher voltage transformers and to facilitate and improve the methods and conditions of manufacture, Hackbridge and Hewittic Electric Co. Ltd. have decided to extend their main transformer assembly bays and test equipment. It is hoped to have this extension available for use within a few months, thereby putting the company in a position to quote much earlier delivery dates for transformers of the largest capacity and highest operating voltages.

This tendency towards larger units applies to the Rectifier division as well as the Transformer division, and during the past 12 months the two largest rectifier installations made by this company were commissioned in the U.S.A. These are the largest glass bulb unit installations in the world.

This news was given in the 1954 statement of the late chairman, Mr. T. F. Lister, whose obituary appears in another column.

New 'platformer' will make better petrol

Work has just begun on the construction of a 'platformer' at Shell Haven oil refinery, on the north bank of the Thames Estuary in Essex. A 'platformer' is so called because the reforming of the feedstock into high quality petrol is carried out in the presence of a platinum catalyst. The plant consists of three sections, namely, feed preparation, reaction and stabilisation. In the first section a naphtha feedstock is distilled to remove the light and heavy ends, the resulting 'heart-cut' being fed to the reaction section, where it is heated and passed at high pressure through a series of reactors containing a catalyst, which is platinum supported on an inert material. The reactor products are cooled and the hydrogen formed on the reaction is separated, compressed and recirculated to the reactors with the feedstock. The liquid product is taken to the last section, where the lighter fractions are removed by distillation and the so-called platformate is ready for blending into high quality motor spirit.

Scheduled for completion towards the end of 1955 and estimated to cost about £2½ million, the new plant will be able to produce some 240,000 tons a year of high-octane components for blending into premium quality petrol for the London and surrounding markets. Ninety per cent. of the equipment is being supplied by British firms and Procon Ltd. are responsible for the design and supervision of the project.

Shell Haven, which has an annual capacity of about 4 million tons, is one of four oil refineries operated by Shell in the U.K. The other three are located at Stanlow, Cheshire; Heysham, Lancs; and Ardrossan, Ayrshire, and the combined capacity of all four plants is 11 million tons a year.

The new 'platformer' is the second

plant of its type to be constructed by Shell in the U.K. The first started work at Stanlow refinery at the end of 1953 and is producing components for blending into aviation spirit.

I.Chem.E. membership and examinations

The Institution of Chemical Engineers has issued, as a 20-page booklet, its 'Regulations for the Admission of Student, Graduate and Corporate Members, and for the Examination of the Institution.'

These regulations represent the first publication in detail by the Institution of its practice with regard to assessment for election to membership, and in addition details are given of a new examination which is to be introduced in 1956 to replace the present Associate Membership Examination.

Foam fire-fighters

Throughout the years that the Air Ministry has been concerned with the fire protection of their airfields by means of 'crash tenders' intensive study and research has been carried out by the Pyrene Co. Ltd. on this important subject. The outcome is the development of an entirely new method of generating mechanical foam. Now the Ministry of Supply has placed a contract with Pyrene on behalf of the Air Ministry for crash tenders equipped with the new foam-making appliances.

These new tenders, the latest form of fire-fighting vehicle designed especially for airfield use, will be capable of producing a total foam output of 6,000 gal. within 1½ min. at the maximum rate of discharge. The provision of a foam monitor enables a powerful, far-reaching jet of foam to be concentrated upon a blazing aircraft immediately the tender reaches the scene of the fire. Under certain conditions the foam monitor can be brought into action as the tender approaches the fire.

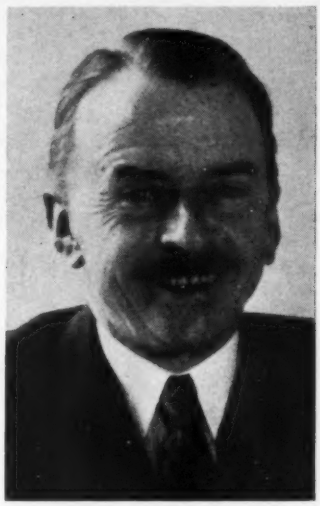
The foam-generating unit is an entirely new innovation that is particularly suitable for embodiment in crash tenders where a great quantity of dense, tenacious, high-quality fire-extinguishing foam is required at a high rate.

A Pyrene foam monitor which provides a powerful initial foam jet up to a distance of 114 ft. is mounted on the roof of the driving compartment and controlled and directed from within the cab. This gives an output of no less than 2,500 gal./min. of foam.

The new crash tender is also equipped with four 60-ft. lines of foam delivery hose, two on each side of the vehicle. In normal practice the two hose lines nearest to the outbreak are brought into action after the foam monitor has made its initial attack on the fire. They enable the crew of the tender to tackle the fire at closer quarters and from different angles. To maintain a powerful discharge of foam from the very beginning it is possible to bring one hose line into operation while the monitor is still in action.

Mr. W. Leonard Hill to lecture at Liverpool

Mr. W. Leonard Hill, chairman of Leonard Hill Ltd., publishers of the Leonard Hill Technical Group, has accepted an invitation from the City of Liverpool Public Libraries Committee to deliver his address 'Making Known' at the Central Public Libraries, William



Mr. W. Leonard Hill.

Brown Street, Liverpool, on Wednesday, October 13, at 7.30 p.m. Mr. Hill originally gave the address in his capacity as chairman of the Agriculture Group of the Society of Chemical Industry at the Annual General Meeting, Burlington House, London, on May 18. The lecture at Liverpool will be the first of a number of Technical Information Lectures to be given during the 1954-5 session and it is being arranged in collaboration with the Association of Special Libraries and Information Bureaux (A.S.L.I.B.).

Other lectures in this series will deal with the subjects of: welding (November 10), British Standards in production engineering (December 8), packaging (January 12), detergents (February 9), and high-voltage engineering (March 9).

NORWAY

Pyrites mines' progress

The mining company Lökken Verk, which operates Norway's biggest pyrites mines, near Trondheim, is celebrating the 300th anniversary of its creation. About 300,000 tons of pyrites a year are now mined. Of the 22 million tons which the mines were estimated to contain originally, only about 6½ million tons remain, sufficient only for another 15 or 20 years at the present rate of extraction. The pyrites yield mostly copper and sulphur, but each ton of pyrites also contains 16 g. of silver and 0.2 g. of gold.

Those of the 1,500 employees of Lökken Verk who have completed 30 years' service are to receive jubilee medals of gold produced from the mines. Altogether 300 of the workers will receive the medal.

Lökken Verk are hoping to increase the degree of refining of the pyrites by a new electrolytic process now being perfected. An experimental plant to test this process is to be built at a cost of £650,000 and should be ready in 1956.

NETHERLANDS

Soda plant

The Upper House of the Netherlands States General has approved legislation to establish a big soda factory in Delfzijl which will put the Netherlands in the world market for this product. One of the Bills approved foresees a State guarantee for a security loan of 21 million guilders. Total capital required is put at 51 million guilders.

The factory will be established by a combine consisting of the Royal Netherlands Salt Industry, the State mines, the Furnace Gases Co., Mekog, and the Royal Netherlands Sulphuric Acid Factories. Raw materials will come from the big salt deposits in Winschoten.

The Lower House approved the project at the end of June.

AUSTRIA

Increasing salt production

The modernisation of Austria's salt mines, which is now in full swing, should be finished next year and is expected to lead to a further rise in production, according to industry sources. At present, annual output comprises 45,000 tons of edible salt, 33,000 tons of industrial salt and 14,000 tons of rock salt.

About 50% of the country's entire salt yield is found in the Ebensee salt mine in the Salzkammergut where a new process using heat and pressure is being introduced. The process, which will also be used in the Hall and Hallein salt mines, is claimed to result in a fuel saving of 60%.

ITALY

New cement factory

A new cement factory, claimed to be the most modern and powerful in Europe, was opened in Naples recently. It was built with funds made available by the Government through the Cassa per il Mezzogiorno and the I.R.I. (the State holding company for industry). The factory will produce upwards of 500,000 tons a year, one-fifth of Italy's domestic needs.

Methane production

In 1953 two milliard cubic metres of methane, 60,000 tons of petrol and 30,000 tons of liquid gas were produced in Italy. Estimates for this year are three milliard cubic metres of methane and 100,000 tons of petrol when a new refinery plant at Cortemaggiore comes into operation. In 1953, 75% of the methane produced was used as an industrial fuel, 7% for the generation of electricity and the remainder distributed between private users, motor traction and the chemical industry.

FRANCE

Butyl rubber plant proposed

Plans for a French butyl rubber plant capable of producing in its initial stages 20,000 tons of the synthetic p.a. have been submitted to the French Government by a group which has been studying the question for three years.

Location of the plant, which would cost some 7,000 to 8,000 million francs, would be Normandy.

The project, as drawn up by the group, would employ isobutylene exclusively. Other raw materials such as alcohol would be too expensive, it is stated.

The group was created in 1951 by prominent oil, chemical and tyre companies, such as Esso Standard, Michelin, Dunlop, Kleber-Colombes, Kuhlmann, Rhone-Poulenc, Pechiney and Ugine.

CANADA

Titanium industry planned

The Minister for Mines, Mr. Prudham, has forecast that Canada will be producing titanium in considerable volume by 1960.

The main obstacle preventing use of the metal is the high cost of production, and Mr. Prudham said his department was attempting to help industry overcome this problem.

Total annual titanium requirements in Canada were negligible at present, said Mr. Prudham, but he estimated that by 1960 Canada would be able to support a titanium industry about one-tenth the size of the U.S. industry.

Primary or sponge titanium now sells for from $4.50 to $5 a pound in the U.S.; it costs from $10 to $15 a pound, however, to fabricate the metal into plates or sheets.

PAKISTAN

Rayon industry

A three-man mission from the Celanese Corporation of America has arrived in Karachi to survey the possibility of establishing a rayon yarn industry in Pakistan. After completing the survey in various parts of the country, the mission will report to the Pakistan Industrial Development Corporation which is sponsoring the survey.

Pakistan at present imports about 20 million rupees' worth of synthetic yarn annually.

HUNGARY

Trainloads of gas

Hungary has decided to supply natural gas to provincial villages and towns by train.

Experts of the Ministry of Town Management who have been working out how to make better use of the country's considerable fields of natural gas will at the beginning of next year start the new service with 12 tanker wagons, each holding 7,500 cu. m.

Instead of a gasworks, all that a town will require is a storage plant into which the gas will be pumped. It is stated that each wagon will make possible an annual saving of 8,300 tons of coal.

★ PERSONAL PARAGRAPHS ★

★ The United Kingdom Atomic Energy Authority announces the appointment of **Mr. K. L. Stretch** as works manager at Calder Hall, Sellafield, Cumberland. It is at Calder Hall that Britain's first atomic power station is now under construction. Mr. Stretch, who will take up his appointment later in the year, is at present with the Salt Division of I.C.I. Ltd. He is an M.A., a Barrister-at-Law and an Associate Member of the Institutes of Civil, Mechanical and Electrical Engineers. He was born in Antigua, British West Indies in 1917 and was educated at the Merchant Taylor's School, Crosby, and King's College, Cambridge. In 1939 he started his apprenticeship with Mather & Platt, Ltd., Manchester, but soon afterwards was commissioned in the Royal Artillery. In 1946 he returned to Mather & Platt to complete his training and worked in the Research Department. He joined I.C.I. in 1948 as instrument manager at the Hillhouse Works, near Blackpool, in the General Chemicals Division. In 1949 he became deputy works engineer at Hillhouse, and in December, 1951, transferred to Salt Division as design engineer. He is married and lives at Sandiway, Cheshire, with his wife and two daughters.

★ **Mr. Harry Godley** has been appointed assistant manager, London Branch Office, Nordberg Manufacturing Co. He became associated with Nordberg in 1945, and in 1946 was named chief engineer in the London office. He came to Nordberg from Messrs. Henry Lees, crane builders of Motherwell, Scotland, where he had been employed as assistant chief engineer and specialist designer. He was with Stothert & Pitt Ltd. for 18 years, and during the latter part of this service he was an engineer and designer in the firm's Quarry and Contractors Plant division.

Mr. H. Godley.

★ **Mr. N. F. Patterson** has been appointed a director of Monsanto Chemicals Ltd. He joined Monsanto in 1946, became works manager at Ruabon in 1947, and in July 1949 was appointed general manager of production, with responsibility for all the production operations of the company.

He is a director also of Monsanto (Soil Conditioners) Ltd. and Monsanto Plastics Ltd., subsidiary companies of Monsanto Chemicals Ltd.

★ **Mr. E. leQ. Herbert,** general manager of Shell Chemical Manufacturing Co. Ltd., has been co-opted as a member of the Council of the Association of British Chemical Manufacturers.

★ **Mr. Guy N. Harcourt,** who was vice-president (Engineering) of the Buflovak Equipment Division of Blaw-Knox Co. of America, is to manage a new section of Blaw Knox Ltd., London, for the manufacture in Britain of *Buflovak* equipment for evaporating, drying, solvent recovery and other processes. He graduated at the Massachusetts Institute of Technology, receiving his Master's Degree in 1911, afterwards being employed by National Aniline & Chemical Co., and the M. W. Kellogg Co. in work connected with organic chemistry and petroleum refining. In the First World War he served with U.S. Army Engineers, being assigned to chemical warfare service.

Joining Buffalo Foundry and Machine Co. (which afterwards became the Buflovak Equipment Division of Blaw-Knox Co.) in 1929, Mr. Harcourt was manager of their New York Office until 1939 when he was appointed vice-president (Engineering) at the Buffalo plant.

He has been a Member of the Council of the American Institute of Chemical Engineers.

★ We announce with regret the death of **Mr. T. F. Lister,** chairman of Hackbridge and Hewittic Electric Co. Ltd., at the age of 71. He was well known in the electrical industry and was chairman of the Council of the British Electrical and Allied Manufacturers' Association in 1951. He was for 20 years with Metropolitan-Vickers Electric Co. Ltd., leaving that company in 1925 to take up the position of manager of the Hackbridge Electric Construction Co. at Walton-on-Thames. In 1926 he was appointed manager also to the Hewittic Electric Co. Ltd., becoming director of both companies in 1931. He became managing director of these companies and also the New Switchgear Construction Co. Ltd. in 1944, and was appointed chairman and managing director in 1946. In 1947-48 he was made chairman and managing director of the newly amalgamated group under the title of Hackbridge and Hewittic Electric Co. Ltd. He retired from the position of managing director in March 1954 but remained chairman of the company.

SOUTH AFRICA

Plastics and chemicals

A £2 million factory which will make a wide range of chemical and plastic products from caustic soda to PVC is being built at Umbogintwini in Natal by African Explosives and Chemical Industries. The new plant is expected to start working in the middle of 1955, and to be in full production by the end of that year.

One of the principal products will be chlorine, and the plant is being developed to supply the requirements of large new factories which will be opened in Natal. These include a paper mill and a rayon pulp factory at Umkomaas.

NEW ZEALAND

Heavy water scheme revived

Agreement has been reached with the United Kingdom Atomic Energy Authority for launching a joint enterprise for the production of heavy water and electric power from geothermal steam bores at Wairakei, in the North Island. The designing of the dual-purpose plant is to be undertaken in the United Kingdom.

The first unit to be installed at Wairakei, in the heart of New Zealand's volcanic area, will produce an estimated 40,000 kw. of electric power. Additions to it will be made in the light of experience gained from its working.

The proposal to develop geothermal steam for the production of heavy water was first made two years ago after a visit to New Zealand by Sir John Cockcroft, director of the British atomic research establishment at Harwell. Last year it was officially announced that the plans had been dropped by Britain on economic grounds. Since then, however, exhaustive proving tests have been undertaken which indicate that sufficient quantities of geothermal steam are available.

It is believed that Britain will supply the scientific and New Zealand the engineering staff for the project.

ALGERIA

Fertiliser, cement and manganese enterprises

Three new companies have been set up in Southern Algeria to manufacture nitrogenous fertilisers, cement and manganese. The first, Société d'Etudes Nord-Africaines de l'Azote, plans to build a 1,500 to 2,000 million franc plant at Colomb-Bechar with a production capacity of 100,000 tons of fertilisers p.a. Founders of the new concern include the French chemical company Air Liquide, the German firm Indufina, the Baillencourt-Coppet group (a Belgian subsidiary of the Italian concern Montecatini), and the Société d'Etudes pour l'Equipement Minier et Industriel.

The last-named firm is also participating in the other two companies. With Ciments Lafarge, it has formed the Société des Ciments Artificiels du Sahara, which is expected to produce at least 30,000 tons of cement p.a. With the French steel industry and the Bureau Industriel Africain, it has set up the Société d'Etudes Nord-Africaines de Ferro-Manganèse, which plans to erect a plant in the Colomb-Bechar area to process locally produced manganese ore and coal.

The Leonard Hill Technical Group—September

Corrosion Technology—Corrosion and Edge Cutlery; Measurement of Plating Thickness; Hot Dip Galvanising; Fretting Corrosion—American Symposium; Painting for the Protection of Outdoor Structures; Petroleum-Based Corrosion Preventives.

Manufacturing Chemist—Process Aspects of Esterification; The Quinoline Drugs; Protection against Radiation by Means of Chemical Agents; Colorimetry and Absorptiometry; Estimation of Volatile Acids in Cough Mixtures; Vitamin Science Progress; Fifty Years of Wax Polish Manufacture; Progress Reports: Disinfectants; Hormones and Analytical Chemistry.

Food Manufacture—Mushroom Growing on Trays; The Lobster, 1; The Higher Alkyl Gallates.

Paint Manufacture—Plant for Paint Manufacturers; Polyvinyl Butyral Resins; Emulsions of Polymeric Materials; Carbon Black for Protective Coatings, 4.

World Crops—Rice Industry in British Guiana; The Cocoa Industry in Nigeria, the British Cameroons and the French Cameroons, 3; Rice Production in the United States; Insecticidal Lacquers.

Fibres—Prediction of Spinning Quality of Olitorius Jute from Simple Tests on Fibre Bundles; Industrial Uses of Terylene Polyester Fibre; Dynel-Rayon Blended Fabrics; Australia makes her own Rayon; Egypt's Competitors; Fibre Data Sheet—Chemical Protein Groundnut Fibres: Ardil and Saralon.

Petroleum—Gamma Radiography in Oil Installations, 2; Lubrication Problems in Relation to Ball and Roller Bearings; Prospects in Petroleum Chemicals, 1; Fire Research, 1953; Canadian Transmountain Oil Pipeline.

Atomics—Scintillation Detectors in Medical and Biological Research, 2; The Second Isotope Conference, Oxford, July, 1954, 1; The Design of Linear Accelerators for X-Ray Therapy.

Building Materials Digest—Finishes and Surface Treatment for Fibre Board; Partitions and Doors of Compressed Straw; Wood Preservatives of the Oil-Solvent Type; Delabole Slate as a Facing Material.

Muck Shifter—Two-deck Bridge over a Bay; Clearing of Woodland for Agriculture, Industry and Housing.

JAPAN

Malayan iron ore mining plan

Subject to the result of a survey carried out last month (August), three companies —one Japanese and two British—are to develop the Temanggan iron ore mine in Malaya, according to a report from Tokyo. The companies concerned are the Kokan Kogyo Co. of Japan, and Boustead and Co. Ltd., and the Andrew Weir organisation of Britain.

A spokesman of Kokan Kogyo said deposits which could be tapped by the mine—situated near Kota Bahru on the east coast of Malaya—were believed to be between 5 million and 20 million tons. Development of the mine was started by the Manyo Iron Manufacturing Co., an affiliate of Kokan Kogyo, before the war, but the work was not proceeded with after the end of hostilities. Yearly output is expected to reach 500,000 tons in the initial stage.

ADEN

Refinery on stream four months ahead of schedule

The coming into operation, four months ahead of schedule, of the Anglo-Iranian Oil Co.'s 5 million tons p.a. oil refinery at Aden is a remarkable feat of planning and construction.

Construction started on November 1, 1952, and the refinery was originally scheduled to be commissioned in December. Construction manpower at its peak was 14,400, a figure which included 1,700 British and Americans and over 10,000 Aden nationals. The remainder were Italians, Indians and Somalis.

The refinery construction has been carried out for Anglo-Iranian by Middle East Bechtel Corporation, an American company, and George Wimpey & Co. of Great Britain. Since the starting date, 192,000 tons of material and equipment have been shipped to Aden, mainly from the United Kingdom and Europe. Of this tonnage, 100,000 tons have been for permanent works in the refinery and port. Imports of food for the employees so far total over 10,000 tons.

The first unit to be finished was the SO_2 Unit, designed to treat 400,000 tons of kerosine a year.

The refinery's two crude units each have a thoroughput capacity of 2½ million tons a year. The main towers, 140 ft. high, 16 ft. in diameter, and weighing 130 tons each, were prefabricated in three sections, shipped to Aden and lifted one section at a time into place. By this method each tower was erected in seven weeks, compared with an estimated seven months had the towers been welded plate by plate on site. These two crude distillation units are the first in the world to be electronically controlled.

Units still to be completed are the *Autofiner*, to desulphurise tractor fuel and the *Platformer*—for producing high quality motor spirit, one of the several being installed in Anglo-Iranian refineries.

In all there will eventually be 101 storage tanks, the biggest for crude oil storage being designed to hold 6,500,000 gal. (24,000 tons).

At the refinery power station, to generate 22,500 kw.—enough electricity to supply a town of 80,000 people—three 7,500 kw. turbo-alternators have been installed. In the salt water pump-house at the power station there are six pumps, each with a capacity of 1 million gal. The boiler battery provides a total of 600,000 lb./hr. of steam for the power station and refinery.

The port is designed to accommodate four 32,000-ton tankers simultaneously.

Two jetties are now in operation. This portion of the project was the responsibility of George Wimpey & Co., as contractor, and Rendel, Palmer & Tritton, the consulting engineers. Over 1 million cu. yd. of rock have been quarried from the nearby volcanic hills and tipped on permanent harbour works.

Most of the 400 miles of piping, ranging in diameter from ½ in. to 6 ft., has been laid in the refinery, and between the refinery and the port. Two 19-mile pipelines, one 16 in. and the other 6 in. in diameter have been laid to join the refinery to tankage in the B.P. International Oil Bunkering installation at Aden.

INDIA

Ferro-manganese industry

The Mineral Advisory Board has been considering the establishment of a ferro-manganese industry in India.

Manganese ore is India's biggest earner of foreign exchange as far as minerals are concerned. The bulk of the ore is consumed in the manufacture of ferro-manganese in U.S.A. and U.K. If the ore is processed into ferro-manganese before export, India's earnings would be many times more than what she obtains for the raw ore.

The raw material required for the manufacture of ferro-manganese, manganese ore, coke and limestone, are available in India. Cheap electric power, essential for electric furnace production of ferro-manganese, would be available from the various hydro-electric and thermal power projects. Besides the high-grade manganese ores in different areas, India has vast deposits of low-grade manganese ores, especially in Orissa and Bombay, which are fortunately very low in phosphorus, an essential requirement for high standard ferro- manganese.

India today imports about 300 tons of ferro-manganese at a cost of about Rs. 1,200 per ton. The estimated cost of production of standard ferro-manganese in electric furnaces in India is said to be approximately Rs. 600 per ton.

UNITED STATES

New nickel refining process

Pure nickel powder and by-product ammonium sulphate are now being produced in commercial quantities, using a new entirely chemical process, according to an announcement by Sherritt Gordon Mines Ltd. The plant which embodies the new process is expected to reach rated capacity some time in autumn.

The start-up of the plant followed the pattern established in the company's Ottawa pilot plant. No troubles were encountered with the process.

The huge refinery, the first of its kind in the world, was designed and constructed by Chemical Construction (Inter-American) Ltd. of Toronto. The process was developed and is controlled jointly By Sherritt & Chemical Construction Corp., a unit of American Cyanamid Co.

Rubber chemical plant

A modern rubber chemical accelerator plant which more than doubles present production has been opened by American Cyanamid Co. at Bound Brook, New Jersey. The new plant is devoted exclusively to the production of Cyanamid's *Nobs* special and *Nobs* No. 1 accelerators.

Both accelerators were developed by American Cyanamid for use in reinforcing (high *p*H) furnace blacks in natural rubber and GR-S. *Nobs* special (N-oxydiethylene benzothiazole-2-sulphenamide) was designed for use where special protection is essential.

Nobs No. 1 is a selected blend of approximately 90% N-oxydiethylene benzothiazole-2-sulphenamide and 10% benzothiazyl disulphide.

Uranium mill

Uranium Reduction Co., organised by Utex Exploration Co and Combined Metals Reduction Co., has applied to the Atomic Energy Commission for a permit to construct a mill at Moab, Utah, to treat uranium ores from the many independent workings in the Utah and Colorado areas. Cost of the mill will be some $4 million.

New fluid catalytic cracking plant

A fluid catalytic cracking plant, claimed to be the largest to be completed to date, went on stream recently at the Girard Point (Philadelphia) refinery of the Gulf Oil Corporation.

Designed and erected by the M. W. Kellogg Co., subsidiary of Pullman Inc., the huge unit is designed for a through-put of at least 63,000 barrels of fresh feed daily, making it the highest capacity plant of its kind ever built.

The cracker is a 'side-by-side' unit, similar to one designed and erected by Kellogg for Gulf at Port Arthur, Texas, in 1951. Erection of the new unit was begun in July 1952, and more than 500 men worked on the project during the peak construction period. It is one of more than 50 fluid units built by Kellogg since the first one was completed in 1942.

Dimensions of the plant's three main vessels are: 56 ft. in diameter by 84 ft. in height for the regenerator; 30 ft. 8 in. by 71 ft. for the reactor; and 20 ft. by 125 ft. for the fractionator tower. The regenerator and reactor are lined with *Kelcrete* insulating concrete and with refractory concrete.

p-xylene for 'Terylene'

The synthetic fibre raw material, *para*-xylene, and other aromatic chemicals will be produced as part of a programme to expand petrochemical production at the Marcus Hook, Pa., refinery of Sinclair Refining Co. A special unit will be built to recover *para*-xylene from a new catalytic reformer already under construction at the refinery.

Initial operation of the unit, which will have a capacity of 10 million lb. p.a., is scheduled for the first quarter of 1955. Sinclair has contracted to supply *para*-xylene to the Hercules Powder Co., who have announced plans for a plant to convert it to dimethyl terephthalate for use by Canadian Industries Ltd. in the production of *Terylene*.

CHEMICAL & PROCESS ENGINEERING

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Stratford House, 9 Eden Street, London, N.W.1

Readers requiring names of suppliers of raw materials, machinery or finished products should complete this form and attach it to their business note-heading. Please state approximate quantities required.

We wish to know names and addresses of suppliers of the following:

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For office use only. No. Date

CATALYSIS

(*Concluded from page 275*)

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